JOURNAL
OF THE
A·I·E·E·

APRIL — 1929

A E E I

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

REGIONAL MEETING, South West District No. 7, Dallas, Texas, May 7-9, 1929

SUMMER CONVENTION, Swampscott, Mass., June 24-28, 1929

PACIFIC COAST CONVENTION, Santa Monica, Calif., September 3-6, 1929

REGIONAL MEETING, Great Lakes District No. 5, Chicago, Illinois, December 2-4, 1929

For future Section Meetings see A. I. E. E. Section Activities in this issue.

MEETINGS OF OTHER SOCIETIES

Institute of Radio Engineers, Engineering Societies Building, New York, N. Y., April 3, 1929

American Welding Society, Annual Meeting, Engineering Societies Building, New York, N. Y., April 24-26, 1929

National Electric Light Association

Middle West Division, Hotel Fontenelle, Omaha, Neb., April 24-26 (T. A. Browne, Lincoln, Neb.)

Southwestern Division, Arlington Hotel, Hot Springs, Ark., April 30-May 3 (S. J. Ballinger, San Antonio Public Service Co., San Antonio, Texas)

East Central Division, Louisville, Ky., May 7-10, (D. L. Gaskill, Greenville, Ohio)

Southeastern Division, Ashville, N. C. May 8-10, (C. M. Killian, 207 Bona Allen Building, Atlanta, Ga.)

American Electrochemical Society, Toronto, May 27-29. C. G. Fink, Columbia University, New York

JOURNAL
OF THE
American Institute of Electrical Engineers

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33 West 39th Street, New York

PUBLICATION COMMITTEE
W. S. Gorsuch, *Chairman*, H. P. Charlesworth, F. L. Hutchinson, Donald McNicol, E. B. Meyer

George R. Metcalfe, *Editor*

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Institute and Related Activities

A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address, be sure to mention the old one, indicating also any changes in business connections.

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American Institute of Electrical Engineers

—*Some Activities and Services Open to Members*—

Library Service.—The Engineering Societies Library is the joint property of the four national societies of Civil, Mining, Mechanical, and Electrical Engineers and comprises one of the most complete technical libraries in existence. Arrangements have been made to place the resources of the library at the disposal of Institute members, wherever located. Books are rented for limited periods, bibliographies prepared on request, copies and translations of articles furnished, etc., at charges which cover merely the cost of the service. The Director of the library will gladly give any information requested as to the scope and cost of any desired service. The library is open from 9 a. m. to 10 p. m. every day except holidays and during July and August, when it closes at 5 p. m.

Employment Service.—The employment service is a joint activity administered by the Civil, Mining, Mechanical, and Electrical Engineering societies and is available to the membership of these societies. Branches of this Department are located in Chicago and San Francisco, the main office being located at the societies headquarters in New York. The service is designed to be mutually helpful to engineers seeking employment, and concerns desiring to secure the services of engineers. This department is financed by contributions from the societies maintaining it and from beneficiaries of the service. Further details will be furnished on request to the Managers of the Employment Service at the main or branch offices, addresses of which will be found elsewhere in this issue.

Presentation of Papers.—An important activity of the Institute is the preparation and presentation of papers before meetings of the Institute. Opportunity is offered for any member to present a paper of general interest to engineers at an Institute meeting, or of having shorter contributions published in the Journal without verbal presentation. In preparing a paper for presentation at a meeting, the first step should be to notify the Meetings and Papers Committee about it so that it may be tentatively scheduled. Programs for the meetings are formulated several months in advance, and unless it is known well in advance that a paper is forthcoming, it may be subject to many months delay before it can be assigned to a definite meeting program. Immediately upon notification, the author will receive a pamphlet entitled "Suggestions to Authors" which gives in brief form, instructions in regard to Institute requirements in the preparation of manuscripts and illustrations. This pamphlet contains many helpful suggestions and its use may avoid much loss of time in making changes to meet Institute requirements.

Manuscripts should be in triplicate and should be submitted at least three months in advance of the date of the meeting for which they are intended. These manuscripts are submitted first to the members of the technical committee covering the subject of the paper, and if approved will next go to the Meetings and Papers Committee for final disposal. After final acceptance, the paper goes to the Editorial department for printing which requires usually from two to three weeks. Advance copies are desired about ten days prior to the meeting in order to distribute the paper to members desiring to discuss it. Considering the routine through which all papers must pass, the advantage of prompt notification and early submission of manuscripts will be apparent.

Publications of the A. I. E. E.—The chief publications of the Institute are the JOURNAL, QUARTERLY TRANSACTIONS, A. I. E. E. STANDARDS, and the YEAR-BOOK.

The JOURNAL, a monthly publication which every member receives, contains two sections, one devoted to technical papers, and the other to current activities of the Institute and other related subjects of engineering interest. The technical section consists largely of rather complete abridgments of the papers presented at conventions and meetings of the Institute. These are brief enough to enable the reader to keep posted in the various fields of engineering which the papers cover; and complete copies of any paper are sent gratis to the reader who wishes to specialize on any subject. The second section of the JOURNAL is designed to keep members acquainted with the activities of the Institute and with the news of the engineering world in general.

The QUARTERLY TRANSACTIONS contain the papers and discussions at Institute meetings and are the only publications in which they are printed in full. These volumes are designed principally for reference books, and are furnished to members at a very nominal cost. These volumes practically constitute the history of the art of electrical engineering, as they contain papers covering every major electrical development.

The A. I. E. E. STANDARDS which were formerly published in a single book have so increased in volume that they are now divided into more than thirty individual sections and the number is constantly growing. This arrangement gives greater latitude in publishing revisions of any sections promptly, and convenient binders are furnished for filing all the individual sections under one cover. An index for the complete set is also available. The standards are supplied to members at a very small cost.

The YEAR-BOOK is published annually and contains an alphabetical and a geographical list of members corrected to January first each year. It also includes a section giving general information about the Institute, the Constitution, By-laws, Code of Principles of Professional Conduct and the Annual Report of the Board of Directors. The Year-Book is sent free to members on request.

JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Vol. XLVIII APRIL, 1929 Number 4

ARE we torch bearers for the engineers of the morrow?

What can and should the profession, working through the Institute, do to furnish the most effective guidance to the engineering novitiate?

This is a major problem of our Committee on Education.

The members of this Committee, representing educators and executives of electrical industries, are giving this subject earnest attention under the able leadership of Chairman Edward Bennett of the University of Wisconsin. They have agreed that the most promising line of first action would be an investigation of means of stimulating the extension of professional education *after graduation.*

The personnel of the Committee gives assurance of worth while accomplishment. Whatever plan or suggestion matures from their deliberations it is certain that the *active aid of practising engineers* will be required to carry it to success. Professor Bennett stated this well last summer in accepting the chairmanship:

> The primary function of the Committee is to bring the thought of the group of practising engineers to bear upon some of the problems of engineering education.

Practising engineers appreciate that it is beyond the scope of colleges to turn out full fledged engineers. The quality of the engineering done by our successors will in a large measure be determined by what the present generation of practitioners does to guide the graduates.

Dr. W. E. Wickenden, Director of Investigation, S.P.E.E., and recently elected President of the Case School of Applied Science, and who has probably given this general subject more complete study than any other one man, in an article sometime ago stated the case thus:

> Engineering education can be bettered in details by the efforts of the colleges acting alone, but it can be made adequate to its task in American life only when it becomes a part of far-seeing plans for the development of our profession and our industries.

The practising engineer must take the lead in developing such plans.

Engineers have thus far done little to foster the growth of group consciousness and professional pride. They have apparently failed to note the beneficial effect on the legal and the medical professions of the attitude taken by lawyers and doctors. In a recent letter Prof. William H. Timbie of Massachusetts Institute of Technology comments on this as follows:

> It seems to me we may well take a leaf out of the book of the medical profession. On the day the young student arrives in the medical college he is called "Doctor" by everybody. When he goes back home at vacation time the local physicians seem to know about him and make it a point to become acquainted with him * * * * Other physicians make it a point to invite him to witness particularly interesting operating cases at the hospital. In fact, everything is done to make him feel that he is one of the profession and to increase his interest and knowledge in the various aspects of his work.
>
> * * * * Surely the older engineers can in a large measure show the same interest in the young engineer graduate that the medical profession does in its younger members.

The educators have their own organization for the discussion of curriculum and related problems in the S. P. E. E. The part that the practitioners should play is common to all branches of engineering. The subject seems to be sufficiently important to warrant the appointment of a semi-permanent committee on education with joint representation from *all* of the national engineering societies.

Meanwhile there are countless ways in which practising electrical engineers can aid through our Sections and Branches.

Chairman Bennett has written an article suggesting some of these ways. This will be found on page 310 of this Journal and its careful reading is commended to all leaders in Section activities.

It rests with you, fellow members, to determine the quality of engineering in the years to come.

R. F. Schuchardt

President.

Some Leaders of the A. I. E. E.

Charles Waterman Stone, Consulting Engineer for the General Electric Company, a Manager of the Institute 1908-1911, and one of its Vice-Presidents 1911-1913, was born in Providence, Rhode Island, Dec. 24, 1874. He attended the public schools in Providence and the West, and later, the University of Kansas for three and a half years. In 1894 he joined the Franklin Electric Company, of Kansas City, but two years later he returned to the East to become machinist for the W. S. Hill Electric Company, of New Bedford, Massachusetts. Where he was shortly advanced to engineer in charge. In 1899 he was chosen superintendent of construction for the Hancock Equipment Company, of Boston, of which he remained a member until he joined the General Electric Company later in that same year. His advancement was steady; starting in the Drafting Department, he was soon made assistant engineer of the Lighting Department; then engineer in charge of the Consulting Engineering Department, manager of the Lighting Department, and finally, manager of the Central Station Department, leading to his ultimate appointment as consulting engineer, his present capacity with the company. He is also consulting engineer for the RCA Photophone Company, Inc., devoting his time wholly to engineering subjects.

While with the W. S. Hill Electric Company, Mr. Stone did much valuable work in the design and construction of switchboards. From 1902 to 1906 he was designing and building power stations and substations, investigating the varying conditions which enter into this situation—working always for improvement in this vitally important branch of electrical engineering. At the same time, he has contributed generously to technical literature with representative papers before the National Electric Light Association, the Association of Edison Illuminating Companies and other professional bodies, and with frequent discussion of other papers, before the Institute and various conventions of the engineering groups. He became an Associate of the Institute in 1903 and in 1912 was transferred to the grade of Fellow, a grade he himself helped to create for the Institute Members, working with a special committee of the Institute to formulate Institute regulations governing this grade.

He is a member of the American Society of Mechanical Engineers, the Society for the Promotion of Engineering Education, the National Electric Light Association, the Society of Engineers of Eastern New York, the Illuminating Engineers, and the Franklin Institute.

While Mr. Stone has never actually assumed the role of teacher, he has lectured frequently before the Engineers School of Washington, D. C., at Columbia University and to other society and college engineering groups. His social contacts have also been broad as a member of the Mohawk Club, the Mohawk Golf Club, the Edison, Schenectady Curling, the Bankers Club of New York, the Lotos Club, the Engineers Club and the Electrical Manufacturers Club.

Beside his work as one of its Managers, and as a Vice-President, Mr. Stone has served the Institute as chairman of various convention committees, on the Code Committee, the Finance Committee, and in many other channels. His opinion has been valued and his endeavor earnest and successful in behalf of the engineering profession.

Reactions Between Insulators

The reactions between insulators built up into a string and the irregular voltage gradient along the assembly are well known, but the influence of the distance apart of the units has only recently attracted attention, as the increase of extra high pressures apparently demands an inordinate increase in the number of insulators to secure the same degree of safety.

A study of the influence of the separation of the insulators in a string was recently published by Niethammer and Nitsche, but the practical results obtained by G. Viel, mentioned in the *Revue Genérale de l'Electricité*, are of particular interest. Insulators of the Hewlett pattern 280 mm. dia. and of the ball and socket Continental pattern 290 mm. dia. were subjected to test in a laboratory at Delle where 750 kv. were available, giving, among others, the following results:

String	Details	Flash-over pressure in kv. Dry	Flash-over pressure in kv. Wet
A	7 standard insulators	430	130
B	9 standard insulators	530	185
C	7 standard insulators with 5 cm. increased separation	520	218

showing that by elongating string "A" of 7 insulators by six spaces of 5 cm. between insulators to form string "C" the flash over pressure was increased in the dry test, 20 per cent., and in the wet test, 70 per cent., whereas, by increasing the number of insulators by 28 per cent and forming string "B" the respective pressures were only increased 22 and 42 per cent. Care was taken to secure accurate results by repeating all tests, and it is believed that the errors cannot exceed 5 per cent, which, considering the class of material tested, may be considered satisfactory.

Sound practise when increasing pressure on a line, for instance from 120 to 150 kv., would seem to be the remodeling of the strings instead of adding insulators, especially as this increases the total length by only 3 cm. with but slight additional outlay. The remodeling of the strings in the manner indicated reduces the potential gradient across the first insulators on a string, and, as it is stated to affect equally both of the standard patterns tested, will no doubt influence the design of high tension insulators and lines.—*World Power.*

Abridgment of

Oscillographs for Recording Transient Phenomena

BY W. A. MARRISON[1]

Associate, A. I. E. E.

Synopsis.—Oscillographs which automatically record amplitude, wave form, frequency, duration, and the time of any electrical disturbances for which they are adapted as developed for recording transient phenomena are described. Two instruments are described or recording very short or very long transients; they may be used in combination. At power frequencies, satisfactory records may be made on films or sensitized paper with a two-watt lamp. The instruments and their performance are illustrated by photographs and oscillograms.

* * * * *

OSCILLOGRAPHS are described which were developed primarily for recording transient phenomena of which the time of occurrence is neither known nor subject to control. The apparatus described was designed primarily for recording transient inductive disturbances in communication lines from neighboring power circuits. For this two somewhat different types of oscillograph were developed. One makes records of short duration having uniform resolution throughout, the other makes long continuous records and may be arranged to record a disturbance of any reasonable duration. The former instrument records on a sheet of film rotating in its plane, and will be called a "polar oscillograph," while the latter records on long strips, such as motion picture film, and will be called a "continuous-film oscillograph."*

Features Common to Both Oscillographs

Since both of these oscillographs were designed for recording the same sort of phenomena and for operating under similar conditions, they have a number of features in common. The light source is a concentrated filament flashlight lamp placed close to a pinhole aperture. Because of the small size of the bulb which permits the filament to be brought very near the aperture, no condensing lens is used. The vibrator is of the moving-iron balanced-armature type similar to a driving element frequently used in loud speakers. With this type of vibrator it is possible to employ a mirror half an inch in diameter, and still retain a satisfactory frequency range and sensitivity. With such a mirror, it is practicable to use a lamp requiring only about two watts. Each oscillograph is equipped with a camera for photographing a clock on the oscillogram to indicate the exact time of occurrence of any disturbance recorded. A schematic diagram of the optical system of the recorder and of the camera, as used in the polar oscillograph, is shown in Fig. 1. A high-speed "line relay" is used with both oscillographs for operating certain automatic devices.

Main Features of Polar Oscillograph

A polar oscillograph is shown in Fig. 2 with the cover removed to show the optical system. The rotating member is separated from the remainder of the oscillograph by a circular light trap which permits free rotation while shielding the film from external light. The circular light trap used is illustrated in Fig. 3. With this arrangement, films may be exposed for days at a time under ordinary light conditions without appreciable fogging.

The chief value of this oscillograph lies in its ability

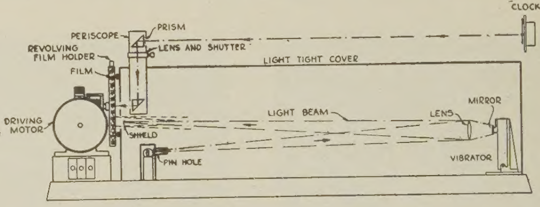


Fig. 1—Essential Elements of Polar Oscillographs

to record with good resolution from the very beginning of a transient. To accomplish this, the lamp is lit continuously and a narrow shield is placed in the light path of just sufficient width to prevent light from reaching the film when the vibrator is at rest. In this way fogging is prevented during the time when no current is flowing in the vibrator but a record is made of any disturbance large enough to move the spot off the shield. This causes a narrow clear space to be left where a zero line is usually obtained. The shield may be removed from the light path when it is desired to record a zero line.

Main Features of Continuous-Film Oscillograph

The continuous-film oscillograph is shown in Fig. 4. It differs from the polar oscillograph mainly in the form in which records are obtained. The instrument shown makes records on motion picture film or sensitized paper of the same width which is advanced by means of a motion picture sprocket driven through gears and a

1. Engineer Bell Telephone Laboratories, Inc., New York, N. Y.

*This instrument is also known as the 'Movie oscillograph.'

Presented at the Regional Meeting of Middle Eastern District, No. 2, Cincinnati, Ohio, March 20-22, 1929. Complete copies upon request.

29-54

magnetic clutch from a variable speed shunt motor. The motor and associated gears are left running during the time a transient may be expected, and, when a disturbance occurs, a quick acting magnetic clutch engages the film driving shaft with the motor and the line relay lights the lamp. The whole recording mechanism may be put in operation within 0.02 second,

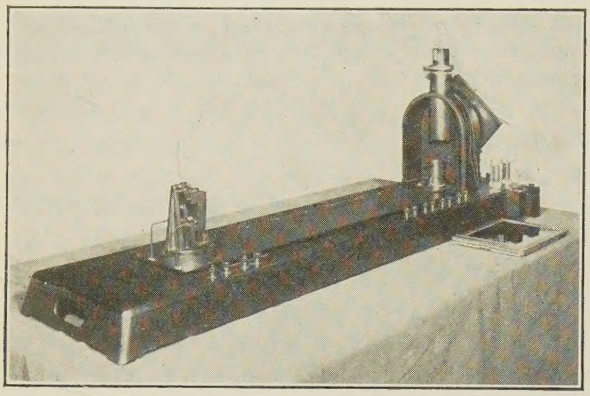


Fig. 2—Polar Oscillograph, Showing Film Rotor, Periscope, Lamp Housing, and Vibrator

thus insuring a good record of any but a very short transient.

With a voltage higher than normal and by the use of the circuit shown in Fig. 5, it is possible to light the

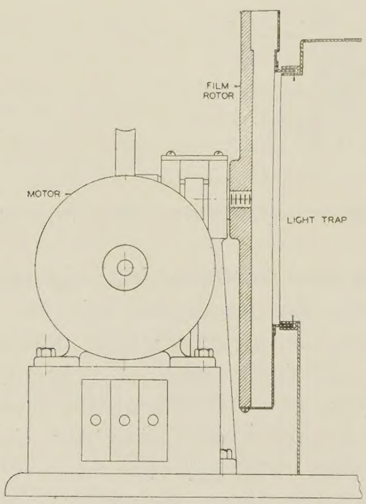


Fig. 3—Scale Drawing of Rotating Light Trap

lamp to full brilliancy within 0.01 of a second. When the lamp circuit is closed the condenser is charged suddenly to the applied voltage, the charging current passing through the filament. The resistance shunting the condenser has such a value that normal current flows through the lamp in the steady state.

The magnetic clutch, while designed to operate quickly, accelerates the sprocket and film without shock. When current flows in the annual coil, (see Fig. 6), a steel diaphram on the driven member is drawn against the circular electromagnet, traction being obtained at the outer edge of the diaphram. Due to the small clearance, and due to the small moment of inertia of the driven member, it is rapidly accelerated to maximum speed.

Operation

There are many ways in which the oscillographs described may be used. In one arrangement, two polar oscillographs and one continuous-film oscillograph have been used together for studying transients likely to occur at any time during long continuous periods.

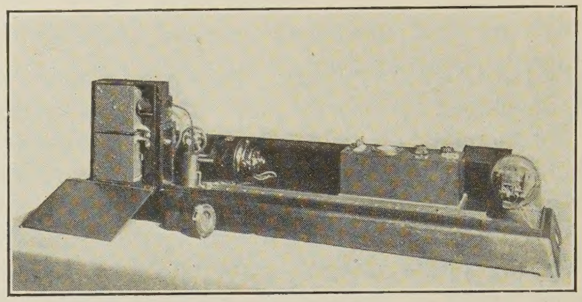


Fig. 4—Continuous-Film Oscillograph With Covers Removed

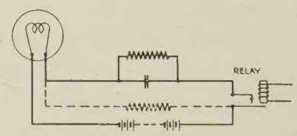


Fig. 5—Circuit for Lighting Lamp Quickly

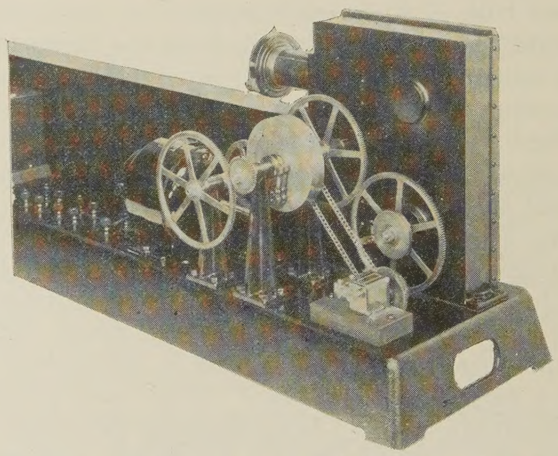


Fig. 6—Quick Acting Magnetic Clutch on Continuous-Film Oscillograph

The arrangement is shown diagrammatically in Fig. 7. One of two polar oscillographs is connected in the circuit being investigated so that it is in condition to record the first part of any transient. A high-speed line relay associated with it is arranged to put the sequence switch in motion, which takes care of a number of operations consisting chiefly of starting the continuous-film oscillograph, substituting the spare polar oscillograph for the first after a short time interval and operating the camera shutters at the proper times.

The polar oscillograph obtains a record of the first part of the transient, while the continuous-film oscillograph obtains a record of the complete transient with the exception of the first few cycles. The record of a transient obtained with the two oscillographs used together is shown in Fig. 8. The polar oscillograph

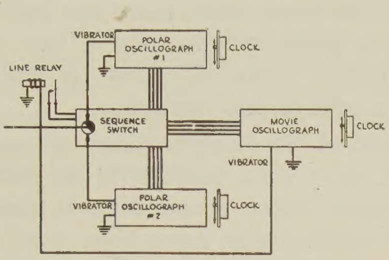


FIG. 7—ARRANGEMENT OF OSCILLOGRAPHS FOR RECORDING ANY TRANSIENT IN A LINE

Two polar oscillographs and one continuous-film with control equipment and clocks are arranged so that a transient of any duration occurring at any time will be recorded with a record of the time of occurrence.

began recording immediately, while the other began about five cycles later and continued 25 or 30 cycles beyond the end of the polar record showing the manner in which the transient ended.

With the continuous film type of oscillograph, a large number of records can be made at one loading. Because of this, it is possible, with the use of an automatic sequence switch, to make the oscillograph entirely

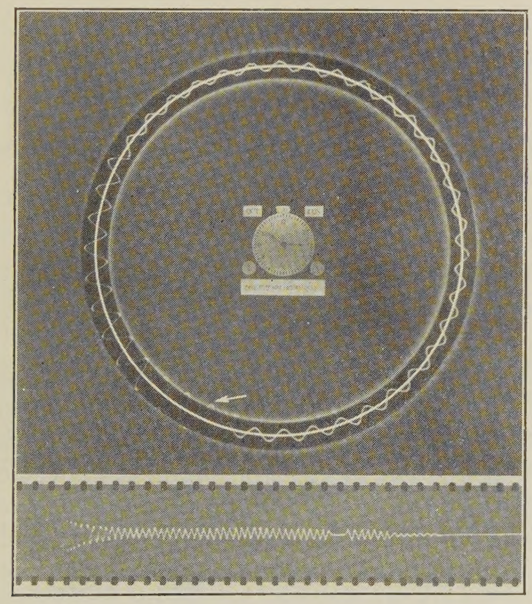


FIG. 8—SAMPLE OF RECORDS MADE BY POLAR AND CONTINUOUS-FILM OSCILLOGRAPHS USED TOGETHER

automatic in operation, causing it to record all of the transients in a circuit as they occur. Such an oscillograph may be left permanently connected into a circuit in which transients are expected, and at the end of any period the film that has been advanced into the "exposed" magazine will have records of the magnitude, frequency, and wave form of the disturbances and of the time of occurrence of each.

A modification of the continuous-film oscillograph is shown in Fig. 9 adapted especially for sampling a wave at regular short intervals instead of making a continuous record or merely a record of unusual disturbances. A rotating mirror sweeps the light beam along the oscillograph film past an aperture A so that the effective

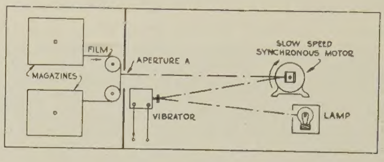


FIG. 9—SCHEMATIC DRAWING OF SAMPLING OSCILLOGRAPH

This oscillograph records one wave out of a number at regular intervals, say one cycle in sixty, with considerable resolution in order to record slow variations in wave form.

film speed during exposures is many times the actual film speed, and permits of exposure during only a small part of the total time. If the distance of the rotating mirror from the film is 8.5 in., one cycle of the wave recorded will be spread over approximately one inch of film. If a rotating mirror with a single facet is used, and if the aperture is just one inch wide, the actual film speed should be one inch in two seconds and every one hundred and twentieth wave will be recorded. The

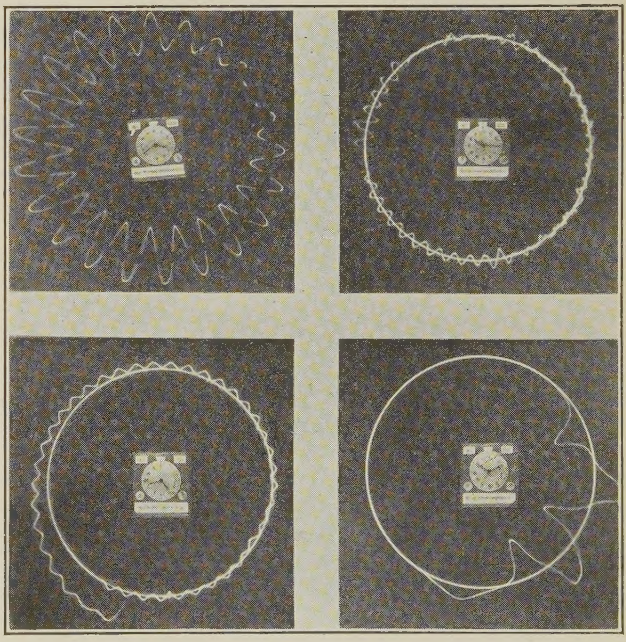


FIG. 10—SAMPLES OF POLAR OSCILLOGRAMS

advantage of this recording method is that good records of slow changes may be obtained without using a large amount of film.

Another method of sampling which gives a somewhat different kind of information may be used with a continuous-film oscillograph with the usual optical system. The film is advanced very slowly and at

intervals the speed is increased by an amount sufficient to show the actual wave form.

Performance

The limitations of an oscillograph lie mostly in the vibrator and, to a smaller degree, in the optical system. The frequency characteristic of the vibrator up to 800 cycles is quite uniform, permitting records of disturbances having components in this range to be made with little distortion. This range includes the first 13 harmonics of 60 cycles and the first 32 harmonics of 25 cycles.

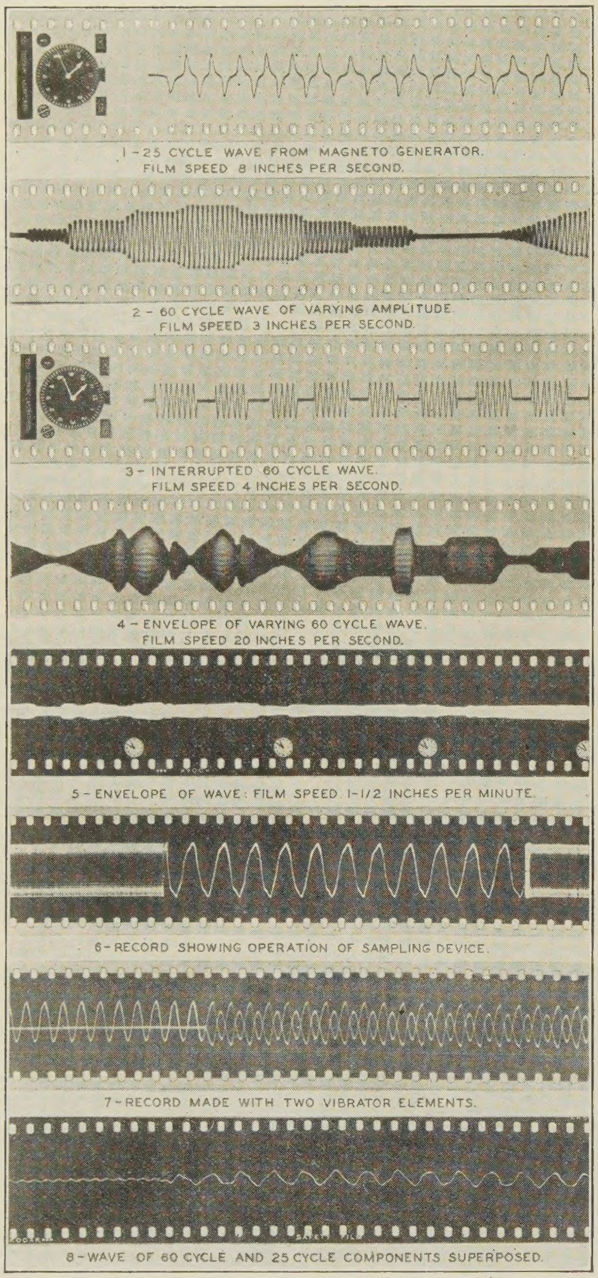


Fig. 11—Samples of Continuous-Film Oscillograms

The vibrator may be wound to have any impedance in a wide range. If wound to have a high impedance, it is especially suited for recording voltage waves; and if wound to have low impedance, it is better suited for recording current waves. The sensitivity varies approximately as the square root of the impedance of the winding.

As noted previously the oscillographs described are intended for recording in a comparatively low frequency range. In the range given there has been no difficulty in obtaining good records with a two candle power flashlight lamp. This, of course, is due to the large size of the mirror on the vibrator.

A number of field applications of oscillographs of both types have been made with satisfactory results. In some cases where cooperative studies were being made, the oscillographs have been used for recording transient neutral currents in power systems as well as to record voltages induced in telephone circuits by power system transients. Experience with the oscillographs in these field installations has suggested a few improvements of a mechanical nature and certain rearrangements of parts to increase the convenience of operation. These changes are now being embodied in a new design. It is hoped that it will be possible in a later paper to describe these features and to give the results of field experience more fully than can be done at this time.

Abridgment of

SHORT-CIRCUIT TESTING ON ALABAMA POWER COMPANY SYSTEM

Its Procedure and Effects on Operation

By H. J. Scholz* and C. B. Hawkins†
Associate, A. I. E. E. Associate, A. I. E. E.

This paper sets forth the reasons for making short-circuit tests upon the system of the Alabama Power Company and describes the methods of testing. The results of the early tests clearly demonstrated the necessity for making such tests and the need for adequate facilities to gather data essential to a full knowledge of the limitations of electrical equipment under actual operating conditions. A description of the modern test equipment installed in the last two years, and the method of procedure in making tests are given. A discussion of the results obtained brings out the point that the expenditures for complete testing facilities have been fully justified and have resulted in the installation of better equipment, improved protection, and a higher grade of service to customers.

*Electrical Engineer, Southeastern Engineering Co., Birmingham, Ala.
†Operating Engineer, Alabama Power Co., Birmingham, Ala.

Presented at the Regional Meeting of the Southern District of the A. I. E. E., Atlanta, Ga., Oct. 29-31, 1928. Complete copies upon request.
28-137

Abridgment of

Vector Presentation of Broad-Band Wave Filters

BY R. F. MALLINA*
Member, A. I. E. E.

and

O. KNACKMUSS*
Non-member

Synopsis.—*The function of a broad-band wave filter of the iterative ladder type in the attenuation band, and outside the attenuation band can be explained very simply when expressed in terms of two characteristic vectors Z_a and Z_b. Drawing the diagram of these vectors, it becomes obvious that the angle between them is the phase shift of the filter and that the natural logarithm of the ratio of their magnitudes is the attenuation.*

The diagram also shows very plainly the relationship between a mid-series and a mid-shunt structure, and the equations for such filters can be derived in a very simple manner from the geometry of one vector triangle.

It is hoped that this simplified presentation of types of filters which are so extensively used in radio, acoustical, and mechanical engineering will be helpful in understanding their physical meaning.

1.0 Broad-Band Filters of the Ladder Type in General

SUPPOSE we measure the impedance of a network as illustrated in Fig. 1 at the point 1, and obtain at the frequency f the value $\mathfrak{Z}_i = \mathfrak{Z}_k$. The impedance $\mathfrak{Z}_i$ we call the input impedance; $\mathfrak{Z}_k$ the iterative impedance.[1]

Then we cut off section a, measure the impedance at point 2, and obtain again $\mathfrak{Z}_i = \mathfrak{Z}_k$. Cutting off sections b and c and always obtaining the measurement $\mathfrak{Z}_i = \mathfrak{Z}_k$ shows that Fig. 1 is a network whose input impedance is equal to the terminating or iterative impedance.

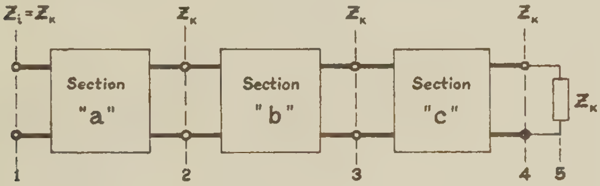


Fig. 1—General Arrangement of an Iterative Structure

A structure of this type is called an iterative structure. The broad-band wave filter of the ladder type is a special case of an iterative structure, and it is this type of filter with which this paper deals.

As will be seen later, it is necessary that with a change of frequency, the terminating impedance $\mathfrak{Z}_k$ must be varied in a certain manner, so that at all times the input impedance $\mathfrak{Z}_i$ is equal to $\mathfrak{Z}_k$.[2]

A broad-band wave filter structure will allow current to pass in a certain frequency band without attenuation, whereas outside this band the current is attenuated considerably.

This fact accounts for the name, filter.

1.1 Two Characteristic Types of Filter Sections. The following two types of filter sections will make $\mathfrak{Z}_i$ equal to $\mathfrak{Z}_k$. The one is called a "mid-series section" (Fig. 2), and the other a "mid-shunt section" (Fig. 3.) The mid-series section Fig. 2 is also called a T section and the mid-shunt section Fig. 3 a π section. There are other special types of filter sections which, however, will not be considered in this paper.

2.0 The Mid-Series Filter Section

2.1 Input Impedance. That the input impedance $\mathfrak{Z}_i$ of a mid-series filter section (Fig. 4) can be made equal to the terminating impedance $\mathfrak{Z}_k$ is shown in the impedance diagram, Fig. 5.

For the purpose of our first illustration, let us choose conditions so that $\mathfrak{Z}_k$ is a pure resistance.

Adding to the terminating impedance $\mathfrak{Z}_k$ the series impedance $X_1/2$ the vector Z_a (Figs. 4 and 5) is obtained. The sum of the reciprocal of Z_a and the vector $1/X_2$ gives us the vector $1/Z_b$ whose reciprocal is then Z_b. Adding $X_1/2$ to Z_b we find that the resulting vector $\mathfrak{Z}_i$ is equal to $\mathfrak{Z}_k$. In other words, having given $\mathfrak{Z}_k$ and X_1 we choose X_2 to have a value such that $\mathfrak{Z}_i = \mathfrak{Z}_k$. The sequence of these operations is indicated in Fig. 5A.

Expressed in vector mathematics we have:[3]

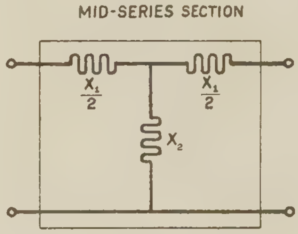


Fig. 2

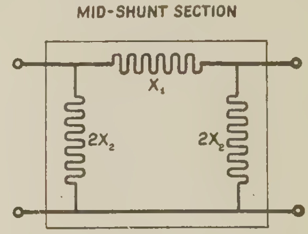


Fig. 3

Figs. 2 & 3—Two Characteristic Types of Filter Sections

*Of the Victor Talking Machine Co., Camden, N. J.

1. So far as possible the same symbols will be employed in this paper as are used in K. S. Johnson's "Transmission Circuits for Telephonic Communication." (A complete list of symbols appears in Appendix A, not included in Abridgment.)

2. In practise, of course, there is no such terminating impedance having the correct value at every frequency. However, it is possible to change certain elements of the network and obtain a close approximation to filter conditions.

3. The symbol $|Z|$ indicates magnitude of Z. The symbol Z without the bars represents a vector having magnitude and direction.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

$$\mathfrak{Z}_k + \frac{X_1}{2} = Z_a$$

$$\frac{1}{Z_a} = \frac{|1|\,\epsilon^{j0}}{|Z_a|\,\epsilon^{j\beta/2}} = \frac{|1|}{|Z_a|}\,\epsilon^{j(-\beta/2)} = \frac{|1|}{|Z_a|}\,\backslash\beta/2$$

In other words, if Z_a is a vector with angle $\left(+\frac{\beta}{2}\right)$ the reciprocal $1/Z_a$ is a vector with angle $\left(-\frac{\beta}{2}\right)$

$$\frac{1}{Z_a} + 2\,\frac{1}{2\,X_2} = \frac{1}{Z_b}$$

$$Z_b + \frac{X_1}{2} = \mathfrak{Z}_i$$

$$\therefore \boxed{\mathfrak{Z}_i = \mathfrak{Z}_k} \tag{1}$$

These vector operations may be repeated for every filter section (Fig. 1) and the diagram (Fig. 5) will always remain the same. Therefore we may say in general terms that the input impedance $\mathfrak{Z}_i$ is equal to the iterative impedance $\mathfrak{Z}_k$ and this in turn is equal to the terminating impedance $\mathfrak{Z}_k$ (Fig. 1 at points 1, 2, 3, and 4).

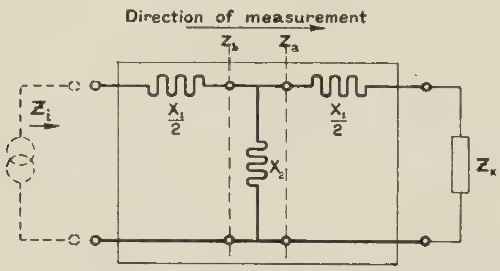


Fig. 4—Circuit of Mid-Series Filter Section

2.2 Iterative Impedance $\mathfrak{Z}_k$. It is clear from the diagram in Fig. 5 that the vector $1/2\,X_2$ must be of such a value that the vector Z_a is in line with the vector $1/Z_b$. If this is not the case, the input impedance is not equal to the terminating impedance and the structure is not the iterative structure described in paragraph 1.1.

From the vector geometry of Fig. 5 we obtain:

$$\frac{X_1}{2} \div \frac{1}{2\,X_2} = Z_a \div \frac{1}{Z_b}$$

$$\therefore X_1\,X_2 = Z_a\,Z_b \tag{2}$$

$$\boxed{Z_a = \mathfrak{Z}_k + \frac{X_1}{2}} \tag{3}$$

$$\boxed{Z_b = \mathfrak{Z}_k - \frac{X_1}{2}} \tag{4}$$

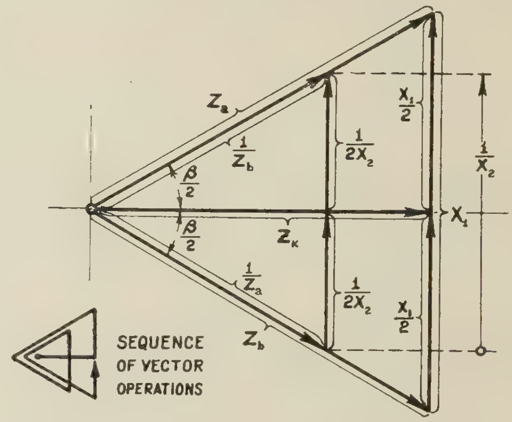
Substituting (3) and (4) in (2)

$$X_1\,X_2 = \left[\mathfrak{Z}_k + \frac{X_1}{2}\right]\left[\mathfrak{Z}_k - \frac{X_1}{2}\right] = (\mathfrak{Z}_k)^2 - \left(\frac{X_1}{2}\right)^2$$

$$\mathfrak{Z}_k = \sqrt{X_1\,X_2 + \left(\frac{X_1}{2}\right)^2}$$

$$\boxed{\mathfrak{Z}_k = \sqrt{X_1\,X_2}\,\sqrt{1 + \frac{1}{4}\,\frac{X_1}{X_2}}} \tag{5}$$

In Fig. 5, vector X_1 and vector $1/X_2$ have the $+j$ direction; such a structure is called a low-pass filter.



5A

Fig. 5—Vector Diagram of a Mid-Series Filter Section

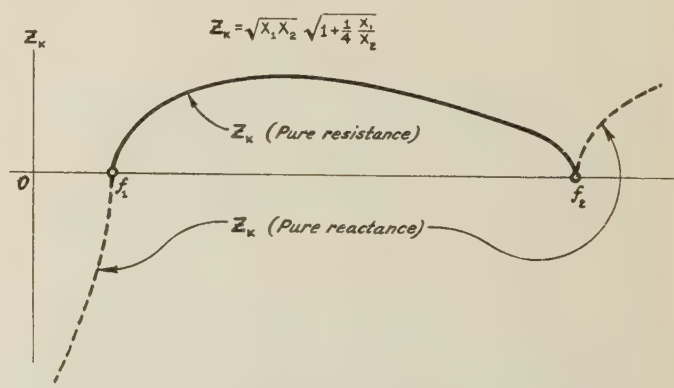


Fig. 6—Iterative Mid-Series Impedance of One Type of Band-Pass Filter

However, Equation (5) may also be obtained when X_1 and $1/X_2$ have the $-j$ direction. This structure is a high-pass filter.

In Equation (5) the reactances X_1 and X_2 are functions of frequency.

Taking the special case of a band-pass filter (Fig. 38A) we may plot Equation (5) and obtain a curve as illustrated in Fig. 6.

It appears from the figure that $\mathfrak{Z}_k$ takes the value zero at two points on the frequency scale, one at f_1 and one at f_2. They are called the cut off frequencies. As will be seen later, between these cut-off points the current passes through the structure without attenuation, whereas it is considerably attenuated outside the frequency cut-off points.

2.3 Iterative Impedance $\mathfrak{Z}_k$ in Vector Diagram. How the impedance $\mathfrak{Z}_k$ is changed from a resistance into a reactance at the points f_1 and f_2 may be illustrated by using the vector diagram of Fig. 5 and varying the value of the impedance vectors X_1 and $1/X_2$ from zero to infinity.

Let us start with a frequency at which the angle β is

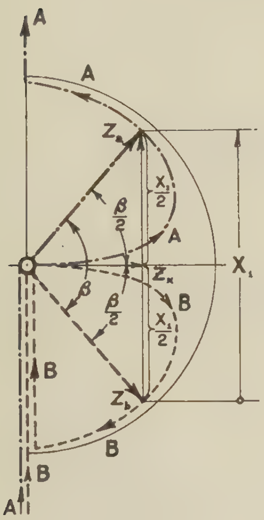


Fig. 7

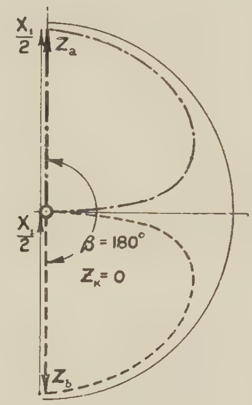


Fig. 8

Fig. 7—Position of the Characteristic Vectors Z_a and Z_b in the Frequency Band

Fig. 8—Position of the Characteristic Vectors Z_a and Z_b at the Upper Cut-Off Frequency f_2

the angle enclosed by Z_a and Z_b in the band-pass filter diagram of Fig. 7.

By varying the frequency up and down (Equations (3) and (4)), the vector Z_a describes the dot-and-dash line, the vector Z_b the dash-line.

The arrows A and B indicate the directions in which the vectors Z_a and Z_b move when the frequency is increased.

If we increase the frequency, we get one limit for $\mathfrak{Z}_k$ as pure resistance when $\beta = 180$ deg. (Fig. 8).

Then

$$Z_a = -Z_b = \frac{X_1}{2} \tag{6}$$

or in other words, Z_a and Z_b are equal in magnitude but have opposite directions. $\mathfrak{Z}_k = 0$ in this case, as is obvious from Fig. 8.

If we decrease the frequency we get the other limit for $\mathfrak{Z}_k$ as pure resistance.

Then

$$Z_a = Z_b = \frac{X_1}{2} = 0 \tag{7}$$

2.4 Resistance and Reactance Limits of $\mathfrak{Z}_k$. The question is now, what happens to $\mathfrak{Z}_k$ when we have increased or decreased the frequency beyond these limits.

From Fig. 7 we can see that X_1 is the difference between the vectors Z_a and Z_b or

$$Z_a - Z_b = X_1 \tag{8}$$

also

$$Z_a = \mathfrak{Z}_k + \frac{X_1}{2} \tag{3}$$

$$Z_b = \mathfrak{Z}_k - \frac{X_1}{2} \tag{4}$$

These equations are also true for $\beta/2 = 90$ deg. Then $\mathfrak{Z}_k$ is zero or a pure reactance and we obtain a condition as shown in Fig. 9.

Fig. 10 represents Equations (8), (3) and (4) when $\beta = 0$.

If we let $X_1/2$ and $1/2\,X_2$ in Fig. 5 increase until $\beta = 180$ deg. and $\mathfrak{Z}_k = 0$, we obtain a vector diagram as shown in Fig. 11. From Fig. 5 it is obvious that assuming the angle β to be 180 deg.:

$$\frac{X_1}{2} = Z_a \tag{9}$$

$$\frac{1}{2\,X_2} = -\frac{1}{Z_a} \tag{10}$$

$$\frac{X_1}{X_2} = -4 \tag{11}$$

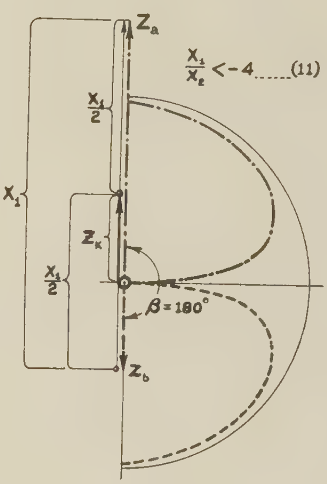


Fig. 9

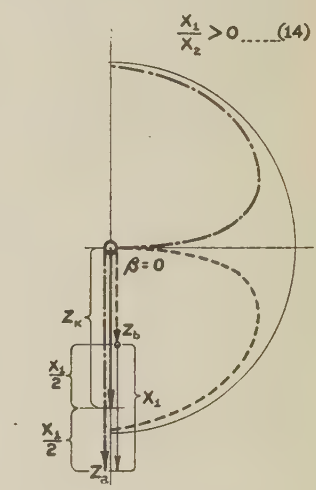


Fig. 10

Figs. 9 & 10—Position of the Charactersitic Vectors Z_a and Z_b Outside the Frequency Band

If we let X_1 in Figs. 5 and 7 decrease until $\beta = 0$, it is clear that

$$\frac{X_1}{2} = 0 \tag{12}$$

$$\frac{1}{2\,X_2} = 0 \tag{13}$$

$$\therefore \frac{X_1}{X_2} = 0 \tag{14}$$

In this way, we may say that assuming the vectors X_1 and X_2 the vector $\bar{Z}_k$ must be a pure resistance when X_1/X_2 is smaller than zero and greater then -4 (Fig. 7)

$$\boxed{0 > \frac{X_1}{X_2} > -4} \tag{15}$$

Outside the band $\bar{Z}_k$ is a pure reactance.

Equations (11) and (14) determine the cut off points f_1 and f_2.

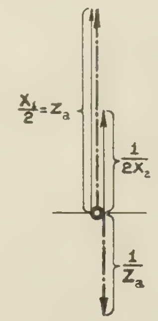


Fig. 11—Position of the Vectors Z_a and $1/Z_a$ at the Upper Cut-Off Frequency f_2

2.5 Current Relations. So far, we have considered impedance relations of the network only. It will be interesting now to see how the current passes through a mid-series filter and what the phase shift and attenuation are at various frequencies.

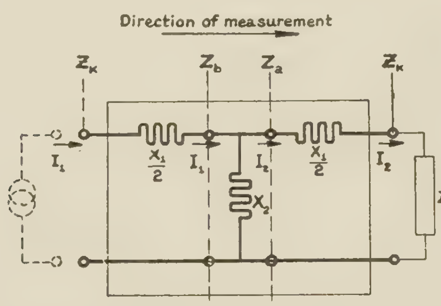


Fig. 12—Circuit of a Mid-Series Filter Section Indicating Current Entering and Leaving the Section

From Fig. 12 we see that the voltage across Z_b is equal to the voltage across Z_a

$$I_1 Z_b = I_2 Z_a$$

$$\frac{I_1}{I_2} = \frac{Z_a}{Z_b} \tag{17}$$

$$\therefore \frac{|I_1|}{|I_2|} = \frac{|Z_a|}{|Z_b|} \tag{18}$$

This equation may be expressed in the exponential form and we obtain

$$\frac{|I_1|}{|I_2|} \equiv \epsilon^A = \frac{|Z_a|}{|Z_b|} \tag{19}$$

$$\therefore \boxed{A = l\,n \frac{|Z_a|}{|Z_b|}} \tag{20}$$

The index A is called the attenuation constant and is the natural logarithm of the ratio of the current magnitude entering the section to the current magnitude leaving it.

2.6 Phase Shift β. Since in the circuit Fig. 12, the current phase shift is equal to the angle between the current I_1 entering the section and the current I_2 leaving it, and since by (17)

$$\frac{I_1}{I_2} = \frac{Z_a}{Z_b} \tag{17}$$

it is obvious that the angle β in Fig. 7 is the phase angle of the filter (Appendix B of the complete paper).

In Fig. 10, Z_a and Z_b have the same direction, $\beta = 0$, and $X_1/X_2 > 0$.

In Fig. 9, Z_a and Z_b have opposite directions $\beta = 180$ deg. and $X_1/X_2 < -4$.

In Fig. 7 the phase angle changes with $\bar{Z}_k$.

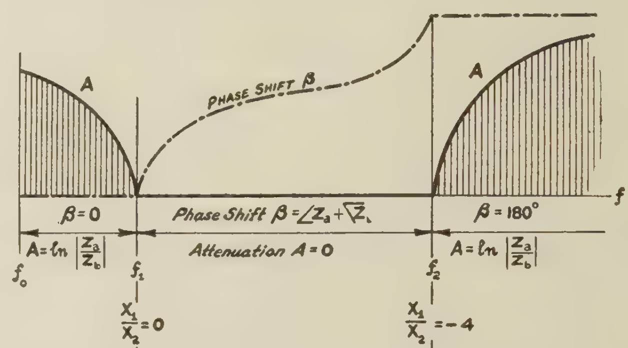


Fig. 13—Attenuation and Phase Shift of One Type of Band-Pass Filter

In general we may say that β is the angle between Z_a and Z_b.

$$\boxed{\beta = \angle Z_a + \backslash Z_b} \tag{21}$$

Fig. 13 shows that the phase shift changes very abruptly near the cut off points.

2.7 Attenuation A. The attenuation in circuit Fig. 12 is zero when the magnitude of the current vector I_1 is equal to the magnitude of the current vector I_2. This is the case in Figs. 7 and 8.

By Equation (19)

$$\frac{|I_1|}{|I_2|} \equiv \epsilon^A = \frac{|Z_a|}{|Z_b|} \tag{19}$$

Letting $|Z_a| = |Z_b|$ (Figs. 8 and 7).

then $A = 0$

In Figs. 9 and 10, Z_a and Z_b are different in magnitude and there will be attenuation of the current.

$$\frac{|I_1|}{|I_2|} = \frac{|Z_a|}{|Z_b|} = \epsilon^A \tag{19}$$

$$\therefore A = l\,n \frac{|Z_a|}{|Z_b|} \tag{20}$$

Assuming the special case of a band-pass filter (Fig. 38a) and plotting Equation (**20**) in terms of frequency, we obtain a curve which changes very abruptly near the cut-off point and which indicates that there is no attenuation in the frequency band between the cut off points f_1 and f_2 or between $X_1/X_2 = 0$, and $X_1/X_2 = -4$ (Fig. 13). Here is presented the basis of the statement made in paragraph 1.0 for definition of a broad-band iterative filter.

The attenuation $A = l\,n\,|\,Z_a/Z_b\,|$ and the phase shift $\beta = \underline{/ Z_a} + \overline{\backslash Z_b}$ can be readily expressed in functions of X_1 and X_2. (See Appendix C of the complete paper.)

The same method which was used to determine attenuation and phase shift for a mid series filter section may be applied to a mid shunt filter section.

Abridgment of

Transient Analysis of A-C. Machinery

BY YU H. KU*

Associate, A. I. E. E.

Synopsis.—*This paper shows how the Heaviside operational methods may be applied to determine the transient currents that are produced in synchronous and induction machines by some sudden alteration of their electric circuits. The observed and computed values of the transient currents have been plotted for a number of cases. There is also a table giving the names of the principal investigators who have written on this subject, and the methods of analysis that they have employed.*

DURING the last 15 or 20 years, the problem of calculating the transient currents in a-c. machinery has become increasingly important. Many notable papers on this subject have appeared in technical literature both in this country and abroad.

In the analysis of these transient problems it is necessary to make some assumptions, either in regard to the nature of the phenomena or in regard to the characteristics of the fundamental physical quantities involved. The earlier authors, such as Steinmetz and Boucherot, followed the first method, while the later authors with few exceptions have followed the second method. The important physical quantities involved are the resistances and inductances of the stator and rotor windings, and the characteristics of the magnetic circuit that enter into the determination of the eddy-current and hysteresis losses. It has been customary to assume that the resistances and self-inductances of the stator and rotor windings are constant, and that the mutual inductance between any two windings varies with the cosine of their relative angular displacement. These assumptions in regard to the inductances are practically equivalent to assuming that the air-gap is uniform and the flux in it, sinusoidally distributed. Whenever eddy currents have been considered, they have been assumed to exist in an electric circuit of constant resistance and self-inductance.

It seems appropriate to present at this time a brief summary of the technical literature by the principal investigators of these transient problems, indicating the type of solution and the essential features of the methods they have employed. Those authors who adopted the foregoing or other reasonable assumptions in regard to the characteristics of the fundamental physical quantities, and those who have carried out the mathematical analysis with rigor, are said to have given an exact solution. All other solutions are classed as approximate. Thus, all cases where the resistances have been neglected or have been taken only partially into account,—as, for example, in determining values for the damping coefficients,—have been classed as approximate even though such solutions may have constituted very important and valuable contributions to this subject.

These transient problems are readily grouped in three general classes. In the first, the circuits on each side of the air-gap are symmetrical; in the second, the circuits on one side of the gap only are symmetrical, and in the third, the circuits on neither side of the gap are symmetrical. Exact solutions for problems in the first two classes can be obtained by operational methods, but those in the third class do not readily lend themselves to mathematical treatment, except in one special case.

In the accompanying table is given the summary of the methods employed by the principal investigators.

After the present investigation had been completed, the Heaviside operational solution by Bekku[1] was brought to the writer's attention. Bekku considered only the case of an alternator with symmetrical excitation, and so, in this slight respect, his solution differs from that presented by the author. In addition, the author believes that such a powerful method deserves to be more widely known than would be possible from Bekku's publication in a foreign journal.

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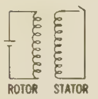
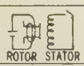
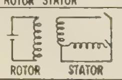
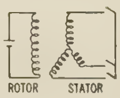
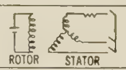
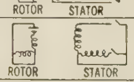
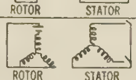
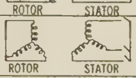
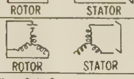
Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1 1929. Complete copies upon request.

1. S. Bekku, "Sudden Short Circuit of an Alternator," *Researches of the Electrotechnical Laboratory*, No. 203, June 1927, Tokyo, Japan.

The following assumptions that have been made conform with the general practise: First it will be assumed that the stator windings are symmetrical and that the rotor is turning at constant speed; second, it will be assumed that the resistances and self-inductances of the windings are constant and that the mutual inductance between any two windings is proportional to the cosine of their relative angular displacement. Thus the effect of frequency upon resistance, the effect of saturation upon inductance, and the effect of harmonics in the distribution of the air-gap flux density are neglected. It should be observed that these assumptions in regard to the inductances cannot be realized except when the machine has a cylindrical rotor. It must also be noted particularly that the solution as here presented does not apply unless the circuits on at least one side of the air-gap are symmetrical. For example, the method does not apply to the sudden single-phase short circuit of an alternator with the usual type of field excitation.

TABLE I

CASE	DIAGRAM OF CONNECTIONS	AUTHOR OF SOLUTION		TYPE OF SOLUTION	ESSENTIAL FEATURES
III		Steinmetz Boucherot Berg Biermanns Doherty Shimidzu and Ito Otake	1909 1911 1915 1915 1918 1922 1924	Approximate Approximate Approximate Exact Approximate Approximate Exact	"Flux Theory" "E.M.F. Theory" For Special Case $r_a/L_a = r_f/L_f$ "Constant Flux Linkages Theorem" Resistances First Neglected. Mathematical
III[1]		Doherty and Nickle	1927	Approximate	Double—Reaction Method and Constant Linkages Theorem
II		Boucherot Laffoon Franklin	1911 1924 1925	Approximate Approximate	"Constant Flux Linkages" Doherty's Method
II		Steinmetz Arnold Diamant Dreyfus Lyon Laffoon Franklin	1909 1913 1915 1916 1923 1924 1925	Approximate Approximate Approximate Exact Exact Approximate Approximate	Boucherot's Method 'Vector' Method 'Vector' Method or Method of 'Shrinking Vectors'.
III		Karapetoff	1925	Approximate	Neglect Resistances
I[2]		Dreyfus	1912	Exact	Mathematical
I[2]		Rudenberg Bekku	1925 1927	Exact Exact	Dreyfus' Vector Method Operational
I		Doherty and Williamson Lyon Dreyfus	1921 1923 1911	Approximate Exact Exact	"M.M.F's. Considered and Const. Flux Linkages' "Shrinking Vectors ' Vector Method
II[2]		Bekku	1927	Exact	Operational

1 Salient Pole Rotor 2 Symmetrical Field Excitation

Briefly, this solution consists in applying first the Stokvis-Fortescue method of symmetrical phase components to reduce the polyphase relations to equivalent single-phase relations; second, an operational method, by which the equations that apply to the stator and rotor circuits and that recognize their relative angular velocity are transformed so that they become similar to the equations that apply to circuits which have no relative rotation; third, the Heaviside operational method, including the principle of superposition as applied to static circuits, employed to determine the integration constants in the solution.

THE OPERATIONAL METHOD

With the foregoing assumptions relative to the character of the resistances and inductances, superposition of currents is possible and the principle underlying Thévenin's[2] theorem can be used in determining the currents which flow when the terminals are suddenly short-circuited. Thus the current in any phase after the short circuit occurs can be considered as the sum of two components: first, that current which would exist if no disturbance occurred; and second, the additional current that would be produced by suddenly applying to the terminals an alternating e. m. f. equal and opposite to the potential existing there before the short circuit.

The operational equations for the alternator's response to the suddenly applied terminal e. m. fs. can be written as follows, reference being made to Fig. 1:

$$(R_1 + L_1\, p)\, i_a + M\, p\, [i_2 \cos n\, t] = v_a\, 1 \tag{1}$$

$$(R_1 + L_1\, p)\, i_b + M\, p \left[i_2 \cos \left(n\, t - \frac{2\,\pi}{3} \right) \right] = v_b\, 1 \tag{2}$$

$$(R_1 + L_1\, p)\, i_c + M\, p \left[i_2 \cos \left(n\, t - \frac{4\,\pi}{3} \right) \right] = v_c\, 1 \tag{3}$$

$$\begin{aligned} (R_2 + L_2\, p)\, i_2 + M\, p \Bigg[i_a \cos n\, t + i_b \cos \left(n\, t - \frac{2\,\pi}{3} \right) \\ + i_c \cos \left(n\, t - \frac{4\,\pi}{3} \right) \Bigg] = 0 \end{aligned} \tag{4}$$

Where

R_1 = resistance of stator, per phase.

R_2 = resistance of field.

L_1 = synchronous self-inductance of stator, per phase. It is the self-inductance of one stator phase, plus the mutual effect of each of the other stator phases.

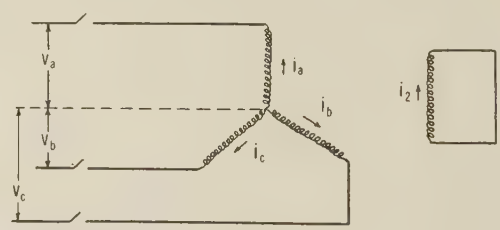


FIG. 1—CONNECTION FOR SUDDEN APPLICATION OF E. M. FS. TO ALTERNATOR TERMINALS

L_2 = self-inductance of field.

M = maximum value of the mutual inductance between one phase of the stator and the field winding.

i_a, i_b, i_c = instantaneous values of stator currents in phases a, b, and c.

i_2 = instantaneous value of field current.

2. L. Thévenin, "Sur un Nouveau Théorème D'Electricité Dynamique," *Comptes Rendus*, Vol. 97, 1883, pp. 159-161. While this theorem was written for the steady state, its extension to the transient case can be readily made.

v_a, v_b, v_c = instantaneous values of the stator terminal potentials in phases a, b, and c.

n = relative angular velocity between windings of stator and field.

$p = \dfrac{d}{d\,t}$, the time differential operator.

1 = unit function. In operational calculus notation this means a time function which is discontinuous at $t = 0$, being zero before and unity thereafter.

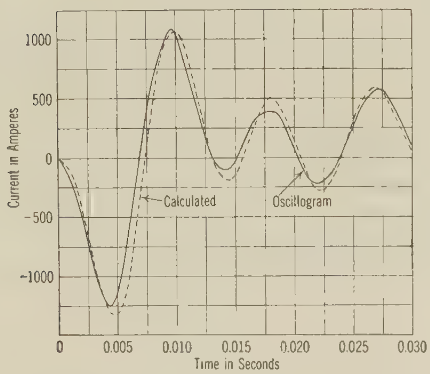


FIG. 2—POLYPHASE SHORT CIRCUIT OF ALTERNATOR AT NO-LOAD CURRENT TRANSIENT IN PHASE A

The full lines represent oscillograph records and the dotted lines the calculated values

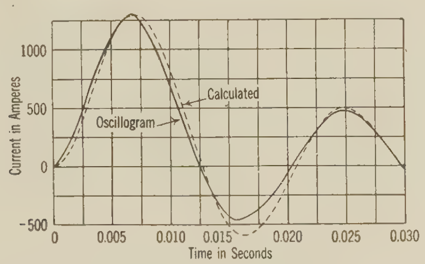


FIG. 3—FIELD CURRENT TRANSIENT CORRESPONDING TO CASE OF FIG. 2

The full lines represent oscillograph records and the dotted lines the calculated values

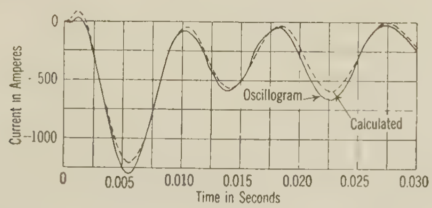


FIG. 4—POLYPHASE SHORT CIRCUIT OF ALTERNATOR HAVING UNITY POWER FACTOR LOAD. CURRENT TRANSIENT IN PHASE a

The full lines represent oscillograph records and the dotted lines the calculated values

If the stator potentials are balanced, the e. m. fs. which are applied to the terminals will also be balanced, so that the sum of their instantaneous values is zero. With no neutral connection, the sum of the instantaneous values of stator currents will also be zero; consequently (3) is obtainable from (1) and (2) and need not be considered further, and (4) can be reduced to an equation in i_2 and the two phase currents i_a and i_b.

By means of the Stokvis-Fortescue scheme[3] of symmetrical component analysis the phase currents and voltages can be replaced by their positive- and negative-sequence components, and the same can be done with the induced e. m. fs. due to the mutual induction. When (1), (2), and (4) are rewritten to include these various relationships, they become

$$(R_1 + L_1\,p)\,(i_+ + i_-) + (e_+ + e_-) = (v_+ + v_-)\,1 \qquad (5)$$

$$(R_1 + L_1\,p)(i_+\,a^2 + i_-\,a) + (e_+\,a^2 + e_-\,a) = (v_+\,a^2 + v_-\,a)\,1 \qquad (6)$$

$$(R_2 + L_2\,p)\,i_2 + \frac{3}{2}\,M\,p\,(i_+\,\epsilon^{-jnt} + i_-\,\epsilon^{jnt}) = 0 \qquad (7)$$

where a and a^2 are $\epsilon^{j\frac{2\pi}{3}}$ and $\epsilon^{j\frac{4\pi}{3}}$ respectively. Solving (5) and (6) simultaneously for v_+ and v_-, and inserting the exponential forms for e_+ and e_-, these two equations reduce to

$$(R_1 + L_1\,p)\,i_+ + \frac{M}{2}\,p\,i_2\,\epsilon^{jnt} = v_+\,1 \qquad (8)$$

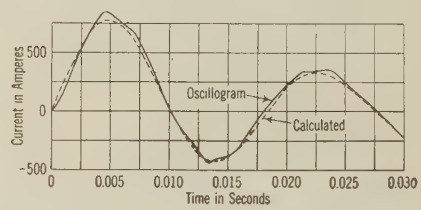


FIG. 5—FIELD CURRENT TRANSIENT CORRESPONDING TO CASE OF FIG. 4

The full lines represent oscillograph records and the dotted lines the calculated values

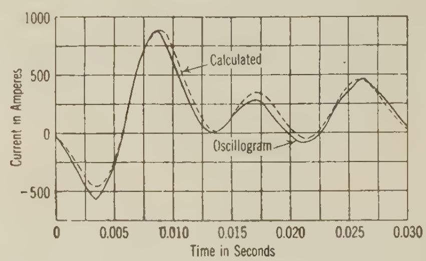


FIG. 6—POLYPHASE SHORT CIRCUIT OF ALTERNATOR HAVING LAGGING POWER-FACTOR LOAD. CURRENT TRANSIENT IN PHASE a

The full lines represent oscillograph records and the dotted lines the calculated values

$$(R_1 + L_1\,p)\,i_- + \frac{M}{2}\,p\,i_2\,\epsilon^{-jnt} = v_-\,1. \qquad (9)$$

If (8) is multiplied by ϵ^{-jnt}, and (9) by ϵ^{jnt}, and these exponentials in every case are shifted to the right

3. L. G. Stokvis, "Sur la Création des Harmoniques 3 dans les Alternateurs par Suite du Déséquilibrage des Phases," *Comptes Rendus*, 159, 1914, pp. 46-49. L. G. Stokvis "Analysis of Unabalanced Three-Phase Systems, *Electrical World*, 65, 1915, pp. 1111-15. R. E. Gilman and C. L. Fortescue, *Single-phase Power Service from Central Stations*, A. I. E. E. TRANS., Vol. XXXV, 1916, pp. 1329-1347. C. L. Fortescue, *Method of Symmetrical Coordinates Applied to the Solution of Polyphase Networks*, A. I. E. E. TRANS., Vol. XXXVII, 1918, pp. 1027-1115.

of the terms containing p by means of the operational shifting transformation,[4] there is obtained

$$[R_1+L_1(p+jn)]\, i_+\, \epsilon^{-jnt} + \frac{M}{2}(p+jn)i_2 = v_+\, \epsilon^{-jnt}\, 1 \quad \textbf{(10)}$$

$$[R_1+L_1(p-jn)]\, i_-\, \epsilon^{jnt} + \frac{M}{2}(p-jn)i_2 = v_-\, \epsilon^{jnt}\, 1 \quad \textbf{(11)}$$

These two, along with (7), form a set of linear equations

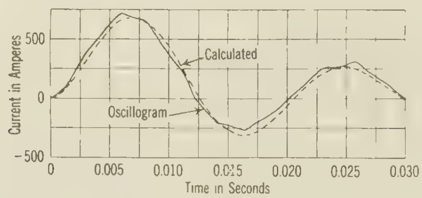


FIG. 7—FIELD CURRENT TRANSIENT CORRESPONDING TO CASE OF FIG. 6

The full lines represent oscillograph records and the dotted lines the calculated values

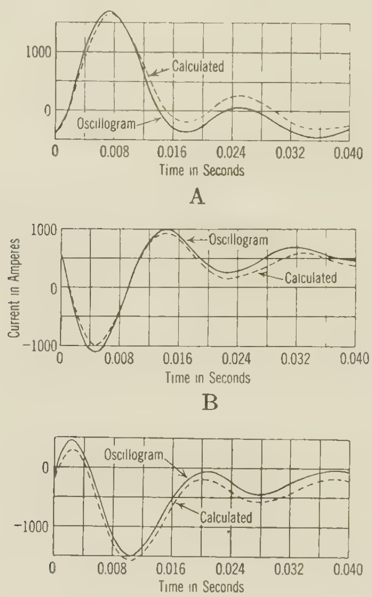


FIG. 8-A, B, C—POLYPHASE SHORT CIRCUIT OF AN INDUCTION MOTOR. STATOR CURRENTS

The full lines represent oscillograph records and the dotted lines the calculated values

in the variables $i_+\, \epsilon^{-jnt}$, $i_-\, \epsilon^{jnt}$, and i_2 which can be solved simultaneously to obtain expressions for each. Thus by a convenient choice of variables, the alternator equations written with a variable mutual inductance to care for the relative rotation between the windings of field and stator can be reduced to those of equivalent stationary circuits.

The expressions obtained for $i_+\, \epsilon^{-jnt}$, $i_-\, \epsilon^{jnt}$ and i_2 will be in terms of the physical constants of the machine and the algebraic quantity p, and thus may be considered operators of the Heaviside form operating upon the unit time function. At this point, the process of solution reduces to the conventional operational problem of interpreting the result of an operator applied to the unit function. A convenient way of making this interpretation in this case is by means of the Heaviside expansion theorem.[5] The results of this evaluation are explicit time functions for each of the three variables.

The rotational features can be returned to the problem by solving the explicit expression for i_+, i_-, and i_2; whereupon the first two can be combined in proper relation to determine the phase currents i_a, i_b, and i_c.

Some results of using this method of calculating the transients of synchronous and induction machines following symmetrical disturbances are given in the accompanying figures. In each case, comparison is

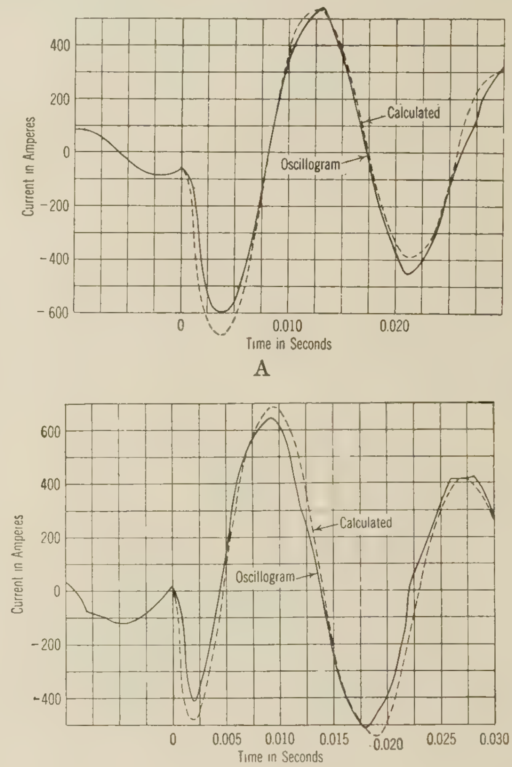


FIG. 9-A, B—SUDDEN VOLTAGE REDUCTION AT INDUCTION-MOTOR TERMINALS. STATOR CURRENTS

The full lines represent oscillograph records and the dotted lines the calculated values

given between calculated curves and oscillograph records. The agreement between computed and observed values is seen to be quite satisfactory.

ACKNOWLEDGMENT

The author wishes to acknowledge his indebtedness to Professor V. Bush and Doctor B. A. Behrend for their suggestions and encouragement; and particularly to Professor W. V. Lyon and Professor M. F. Gardner, who have revised the paper for publication. Credit is also due to those former graduate students of the Massachusetts Institute of Technology whose theses were the source of helpful experimental results.

4. O. Heaviside, "Electromagnetic Theory," Vol. II, p. 294. V. Bush, "Operational Circuit Analysis," (Wiley), 1929, Ch. VIII, Sec. 10.

5. L. Cohen, "The Heaviside Expansion Theorem," *Jour. Franklin Inst.*, 194, 1922, pp. 765-770. V. Bush, *loc. cit.*, Chap. VII, Sec. 4.

Abridgment of

The Condenser Motor

BY BENJAMIN F. BAILEY[1]

Fellow, A. I. E. E.

***Synopsis.**—After a brief description of the construction and connections of the condenser motor, the necessity of varying the capacitance is discussed and the performance at start and under load considered. Locus diagrams illustrating the operating performance in detail are given, followed by a more detailed discussion of starting torque. The Appendix gives the mathematical derivation of many of the formulas discussed.*

THE connections of a single-phase condenser motor are shown in Fig. 1. The motor itself is identical with a two-phase induction motor with the exception of the fact that the two windings are not necessarily alike. Winding 2 may have more or less turns than winding 1. The total weight of copper in the two, however, is approximately the same. The rotor is identical with that of any polyphase motor. It

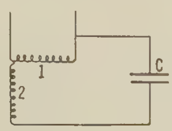


FIG. 1—SIMPLE CONDENSER MOTOR

usually is of squirrel-cage type, although a wound rotor may of course be used.

To obtain the best results, the capacitance should be large when the motor is being started and should be gradually reduced as the speed is increased. In practise, a fixed value of capacitance may be satisfactory,

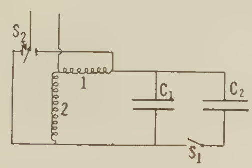


FIG. 2—CONDENSER MOTOR, REVERSIBLE AND WITH VARIABLE CAPACITANCE

providing a starting torque of about 50 per cent of full-load running torque is sufficient. If more starting torque is necessary, the motor may be connected as shown in Fig. 2. The switch S_1 is closed when the motor is at rest and is opened (usually automatically) when the speed is sufficiently high. Fig. 2 also illustrates a method by which the direction of rotation of the motor may be reversed by throwing the switch S_2 to the right or left.

Instead of using two condensers, it is possible to supply the condensers through a variable ratio transformer as shown in Fig. 3. By applying a high voltage to the condenser at start and a smaller voltage for running, the same effect is produced as though the capacitance was changed. With this scheme, the efficiency will necessarily be a little lower due to the losses in the transformer.

The vector diagram of a condenser motor is shown in Fig. 4. This was plotted from an actual test of a small motor under full load. In this case, the motor was a standard two-phase motor.

As usual, the current I_1 in phase 1 lags, by a con-

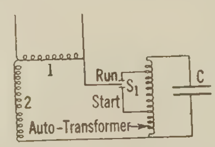


FIG. 3—CONDENSER MOTOR WITH VARIABLE TRANSFORMER

siderable angle behind the line voltage E. Due to the introduction of the condenser, the current I_2 in phase 2 may be made to lead the line voltage. When the proper capacitance is used, the two currents are approximately at right angles to one another and if the two windings are alike, are nearly equal. Under these

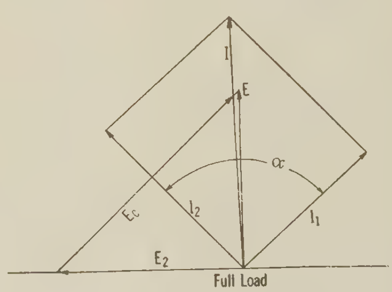


FIG. 4—VECTOR DIAGRAM OF CONDENSER MOTOR. (FULL LOAD)

conditions, the motor will operate just as though it were a two-phase motor and of course with the same efficiency.

From the above it will be apparent that we can build a single-phase motor having at full load practically the same efficiency as a two-phase motor and operating at or near 100 per cent power factor. It is self-evident that its characteristics will be much better than those of a single-phase motor of the usual construction which

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

necessarily operates at a lower efficiency and power factor than a two-phase motor.

In the starting performance, the condenser motor is somewhat superior to the two-phase motor. Since one current leads and the other lags, the combined starting current is the vector sum of the two and is less than their arithmetical sum. For the same reason, the power

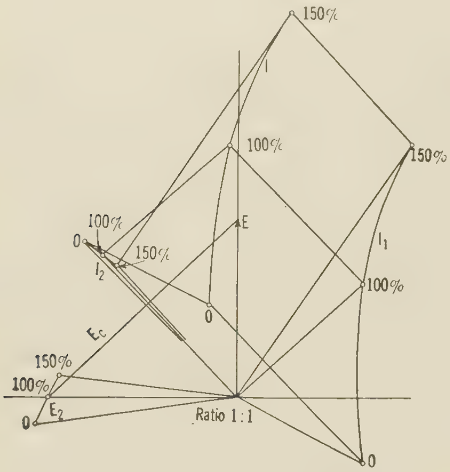

Fig. 7—Locus Diagram of Condenser Motor. Winding Ratio 1 to 1

factor is excellent and is usually close to 100 per cent. The motor will develop even more torque than a two-phase motor and the current required is substantially less; in fact, the torque per ampere is nearly double that of a two-phase motor.

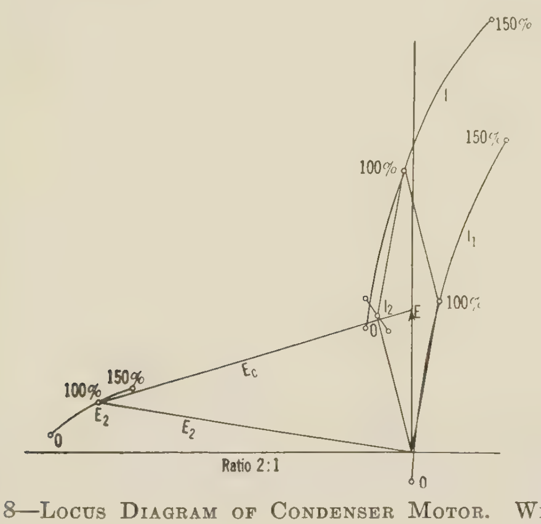

Fig. 8—Locus Diagram of Condenser Motor. Winding Ratio 2 to 1

Locus Diagrams

The action of the motor under varying loads is shown in the locus diagram of Fig. 7. The curve marked I_1 represents the locus of the vector I_1 as the load is changed. The small circles represent the positions of the end of the vectors corresponding to no-load, full load, and 50 per cent over load. Similarly, the short curves marked E_2 and I_2 represent the loci of the vectors representing the voltage across phase 2 and the current in phase 2. The curve marked I is the locus of the line current. In this particular case the current was leading at light load, in phase with the voltage at a little over full load, and slightly lagging for 50 per cent over load. The power factor throughout this range of load was very close to 100 per cent.

Fig. 8 shows a locus diagram for the same motor but connected so that phase 2 has twice as many turns as phase 1. The voltage across phase 2 is of course nearly twice as great as before. The condenser voltage obtained by drawing a line from any point on the curve E_2 to the end of the vector E is more nearly at right angles to E than before. Since the current I_2 must be at right angles to the condenser voltage, it is brought more nearly into phase with E. Since the capacitance used was such as to give nearly 100 per cent power factor to the motor as a whole, it follows that the current I_1

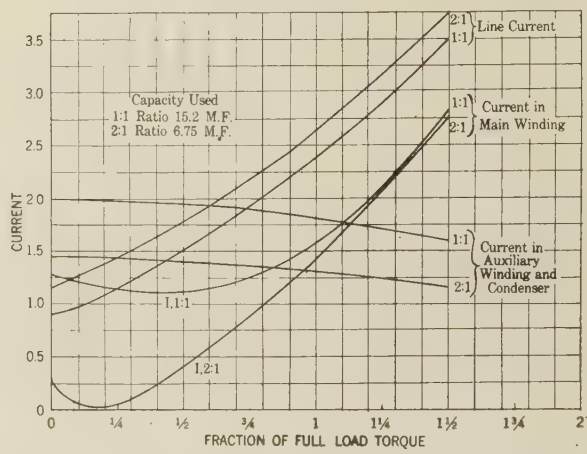

Fig. 9—Torques and Currents in the Different Windings of Condenser Motor

was forced to be more nearly in phase with the line voltage. The vector sum of the two is represented by the current I (the line current), and this is at nearly 100 per cent power factor throughout the range of the motor.

The advantage of having more turns in winding 2 than in winding 1 is that a higher voltage is applied to the condenser, and consequently, the capacitance can be greatly reduced; in fact the condenser used in making the tests represented in Fig. 8 was approximately one-half as large as that used in the tests of Fig. 7. It will of course be apparent that since the two currents I_1 and I_2 are no longer at right angles the motor is not operating so efficiently. In fact, the conditions approach those of the ordinary single-phase motor, since the current I_1 and I_2 do not differ very greatly in phase. The power factor is still excellent, but the efficiency of the motor is somewhat reduced.

Fig. 9 has been plotted from the same data used in Figs. 4 to 8, and shows the variation of the various currents with the torque. Similarly, Fig. 10 shows the

variation of the $I^2\ R$ losses in the different windings.

Comparison of Watts

In Fig. 11 the total watt input to the motor, and also the watts in each of the windings, have been plotted. The watts in the auxiliary winding are nearly the same with either connection, and decrease only slightly as the load increases. The watts in the main winding are in both cases negative with light loads and of course increase as the load increases. The total power required with the two to one connection is greater than with the one to one connection on account of the reduced efficiency.

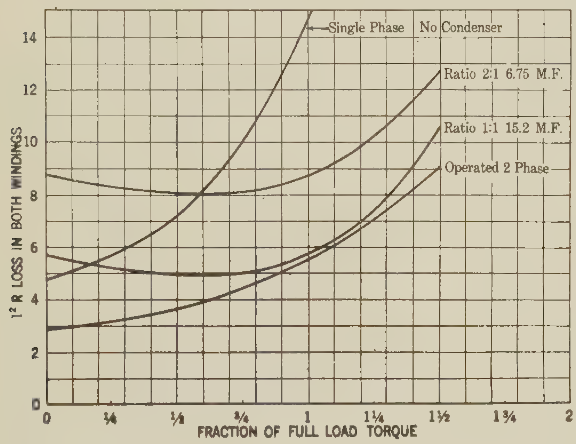

Fig. 10—Torque and $I^2\ R$ Losses in Condenser Motor

Effect of Changing Capacitance

It will be evident from the preceding discussion that the characteristics of a motor will be radically modified by any change in capacitance. The results of a test upon the same motor, previously referred to, have been embodied in Fig. 12, which shows the currents plotted in their proper phase relation, the output being held constant while the capacitance was varied.

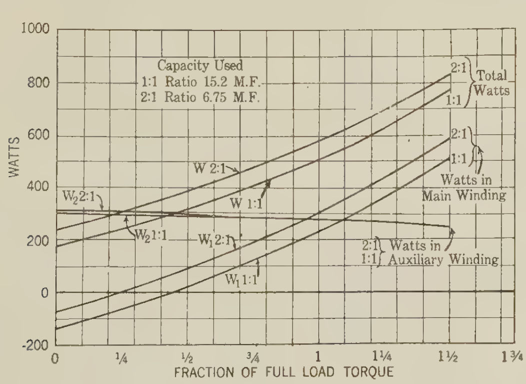

Fig. 11—Torques and Watts in Condenser Motor

It will be noted in both of these curves that the power component of the current,—that is, the projection of the current upon the voltage axis,—is less with the current somewhat lagging than it is with 100 per cent power factor. At full load the minimum power input, and consequently the highest efficiency, is obtained with a capacitance of about five microfarads, and at half load with about three microfarads. The lowered efficiency, as previously explained, is due to the fact that the current does not divide between the two windings in the best ratio. In general, therefore, the capacitance which gives the best power factor will not necessarily be that which gives the highest efficiency. Particularly in the case of motors with a large number of turns in winding 2 compared with winding 1, it will be necessary to use a capacitance giving a somewhat lagging current if the best efficiency is to be obtained. With a one to one ratio, the points of best power factor and best efficiency will usually come more nearly together.

Starting Torque

As shown in the appendix the starting torque is given by the equation

$$T = Q\ N_1\ N_2\ I_1\ I_2 \sin \alpha.$$

The maximum current will exist in circuit 2 when the circuit is in resonance but under these circumstances the angle between the two currents will be unfavorable and consequently the greatest possible torque will not be developed.

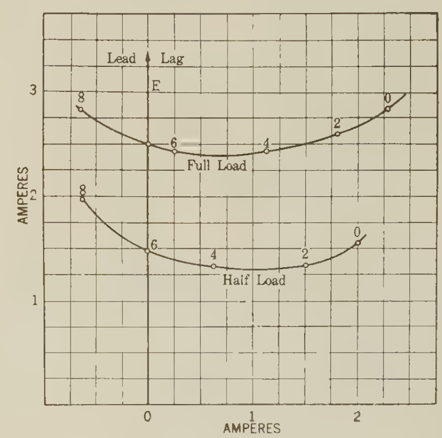

Fig. 12—Locus Diagram of Condenser Motor. Variable Capacitance and Constant Output. Winding Ratio 2 to 1

It is shown in the Appendix (in the complete paper) that the maximum starting torque is obtained when

$$X_3 = \frac{1}{C\ \omega} = -\ K^2\ Z_1$$

in which Z_1 is the impedance of circuit 1, C is the capacitance of the condenser in farads, and $\omega = 2\ \pi\ f$. K is the ratio of turns in winding 2 to the turns in winding 1.

The negative sign indicates that the reactance X_3 is due to a condenser and not to a reactor. If we should use a reactor of the same value it would give us another but much smaller maximum value of torque. In the following the negative sign will be ignored when we are dealing with capacitance only. If the two windings are formed with coils of the same dimensions and if

they contain the same weight of wire, the resistances, inductances, and impedances will all be in the ratio of K^2, K being the ratio of the turns in winding 2 to those in winding 1.

In the above formula, then, $K^2 Z_1$ is the impedance of winding 2, and for maximum torque this impedance should be equal to the reactance of the condenser. On the other hand the condition for resonance would be that the reactance of winding 2 should equal the reactance of the condenser.

It is shown in the Appendix, that the locked torque is given by the following equation,

$$T = \frac{K N_1^2 E^2}{Z_1^2} \cdot \frac{R_1 C \omega}{K^4 Z_1^2 C^2 \omega^2 - 2 K^2 X_1 C \omega + 1}$$

in which the symbols have the same significance as before.

Using the capacitance to give maximum torque; namely, $C = \dfrac{1}{K^2 Z_1 \omega}$, we obtain the following for the maximum torque with any given ratio of turns:

$$T_m = \frac{N_1^2 E^2}{2 K Z_1^2} \cdot \sqrt{\frac{Z_1 + X_1}{Z_1 - X_1}}$$

Relation of Torque and Volt-Amperes in the Condenser

As shown in the appendix, the equation for torque may be written as follows:

$$T = \frac{K N_1^2 R_1}{Z_1^2} E_c I_c = \frac{K N_1^2 R_1}{Z_1^2} \cdot E_c I_2$$

In other words, the torque is directly proportional to the product of the volts across the condenser and the current flowing in it.

If we insert the values of the constants of this particular motor, we obtain the equation

$$T = 0.116 \, K E_c I_2$$

The test results on this motor have been plotted with reasonably good correspondence between them and the calculated results.

The variation of the voltage across the condenser as we change the capacitance is also shown in the curves of Fig. 13. The voltage for any ratio between the turns is the same as the line voltage for $C = 0$, rises rapidly as C is increased up to the point of resonance, and then decreases. As we should expect from the theory the maximum torque is found with a value of C somewhat greater than that which gives resonance.

However, the condenser voltage at maximum torque is usually decidedly above line voltage.

The condenser voltage at the point of maximum torque is given by the following formula:

$$E_c = - E \sqrt{\frac{Z_1}{2 (Z_1 - X_1)}}$$

It will be seen that this value is independent of the ratio K, and in the case of this particular motor, the computed value is 274 volts. The actual values agreed fairly well with this, being 260 where $K = 1$ and 280 volts where $K = 2$.

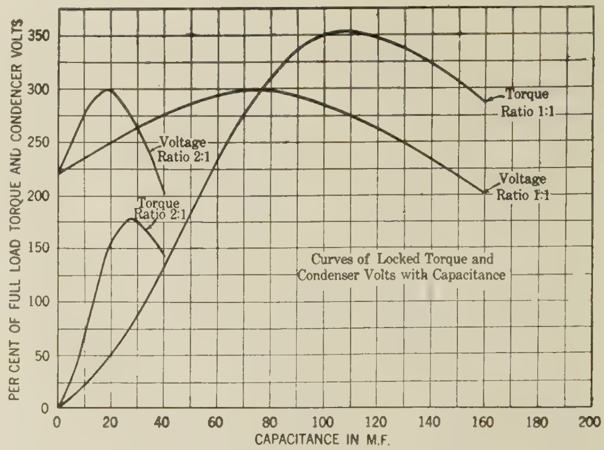

Fig. 13—Variation of Torque and Condenser Voltage with Capacitance

Summary

From the preceding, it will be obvious that as we increase the number of turns in winding 2, the maximum locked torque decreases. However, the capacitance needed decreases even faster, so that if locked torque only is to be considered, the ratio K of the turns should be as great as possible and still permit the necessary torque to be developed.

It will also be apparent from the equation for maximum torque that this may be made as great as desired provided we make K small enough. Excessive torques are however obtained at the expense of large currents and excessive cost of condensers.

Starting Efficiency

The efficiency of the motor increases with the torque and reaches higher values with the smaller values of the ratio K. The maximum efficiency obtained was 45 per cent.

Complete Torque Curves

In the actual application of the motor, we need to know not only the locked starting torque but the torque throughout the complete range of operation. Fig. 16 shows speed—torque curves for another motor with a ratio of turns of 1 to one and with various values of capacitance. It will be seen that the torque with the large values of capacitance is substantially maintained until the motor has reached normal operating speed. As the capacitance becomes smaller, there is a greater tendency toward development of points of low torque at certain speeds. This will be particularly apparent in the curve for 20 μ f. The point of lowest torque occurs at about one-seventh of synchronous speed and would seem to indicate the presence of a backwardly rotating 7th harmonic.

The curve of current taken when a 40-μ f. condenser was used also plotted. It will be seen that the current remains nearly constant throughout the entire starting period.

Abridgment of

Theoretical and Field Investigations of Lightning

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and
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Synopsis.—*This paper gives a review of some recent developments in the methods of studying lightning phenomena. The Norinder form of cathode ray oscillograph and its application in Tennessee are discussed, together with the information secured.*

The second part gives the theory of traveling waves along transmission lines. Reflections at open and grounded ends are considered. A mirror scheme of an infinite series of waves on a double infinite line equivalent to actual waves along a finite line is developed.

The third part discusses the manner in which surges are actually produced on lines by lightning and the effect of ground resistance on the protection afforded by ground wires, both with respect to induced and direct strokes.

The Importance of Lightning Research. During the last few years the increasing importance of the solution of the lightning problem in electrical systems, particularly in long transmission circuits, has resulted in a tremendous increase in the amount of attention given the problem all over the world. Electrical systems are being reconstructed with the idea of generation in large plants at the most economic point, and interconnection between such plants and this added to the natural growth involves expenditures in the central station industry of nearly a billion dollars a year, of which possibly 150 million dollars a year is expended for transmission circuits. Under the present conditions lightning has been found to be the operating condition which limits the design of transmission circuits. The electrical industry must accept the fact that these enormous expenditures warrant fully whatever research expenditure and effort may be necessary to provide the solution to the lightning problem.

I. Recent Developments in Field Investigations of Lightning

Application of Cathode Ray Oscillograph. Since the first introduction of cathode ray oscillographs into laboratory study of transient phenomena, it has been realized that this instrument would be ideal for the determination of the character of lightning voltages in exposed circuits. However, there have been barriers to this use of the cathode ray oscillograph which seemed at the start to be insurmountable. The major difficulty has been in providing means for having the oscillograph in operation on the arrival of the transient. It is essential to the solution of the problem to secure records of the entire duration of the abnormal voltages, and particularly of the beginning of the wave fronts. Thus, if means are devised to anticipate a transient which may occur at any time, it is necessary that the oscillograph be started by the transient itself and with zero delay. This is a problem of no small magnitude.

The Norinder Cathode Ray Oscillograph. In 1927 it came to our attention that successful work had been done by Doctor Harald Norinder of the Swedish Royal Board of Waterfalls, Upsala, Sweden, in making cathode ray oscillograms of actual lightning voltages.[2] It proved that Doctor Norinder's results had been secured by means of an ingenious improvement over the previously known forms of cathode ray oscillographs by which operation is made entirely automatic on the arrival of the transient. Fig. 5 illustrates the scheme invented by Doctor Norinder.

Use of Norinder Oscillographs in Field Studies.

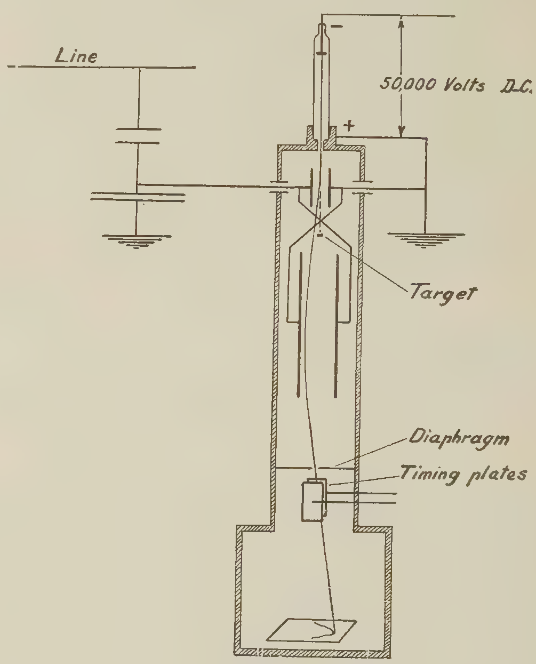

Fig. 5—Diagramatic Scheme of Norinder Oscillograph

Laboratory trials substantiated the experience of Doctor Norinder in establishing the usefulness of the instrument. It was felt to be necessary, however, to get the final assurance by a trial installation in the field that the instrument will give all the information which

1. All of the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

2. Dr. Harald Norinder, "Some Electrophysical Conditions Determining Lightning Surges," *Journal Franklin Institute,* June 1928.

Dr. Harald Norinder, *The Cathode Ray Oscillograph as Used in the Study of Lightning and Other Surges on Transmission Lines,* A. I. E. E. Quarterly Trans., Vol. 47, No. 2, p. 446.

is needed. Arrangements were accordingly made for an installation of two instruments in Tennessee and a second installation of a single instrument in Illinois.

The Tennessee location was chosen, as it met the requirements of a test for this purpose—a highly insulated line in a territory where lightning storms are very frequent. A detailed survey of the operating record and of the location showed that the most suitable point on the line would be where it passes over the western end of the Chilhowee Ridge of the Great Smoky Mountains. Through the cooperation of the Knoxville Power Company and the Aluminum Company of America, arrangements were made for locating two stations, one on each side of the Chilhowee Ridge.

The general arrangement of the test stations is indicated by the diagram of Fig. 7.

The oscillographs and accessories were designed and built during the period between January and about the first of June, 1928. Installations in the field were completed by the early part of July, and from this time, the stations were ready to record any lightning which occurred.

It was planned to make the first few records using the rotating film in order to get a general picture of the nature of the surges and then to take later records using the oscillator for the time scale deflections. Unfortunately, however, only a single disturbance of appreciable magnitude appeared on the line during the period between the time when the apparatus was set up until November 4 when the test was discontinued for the year. This record is shown in Fig. 13. No

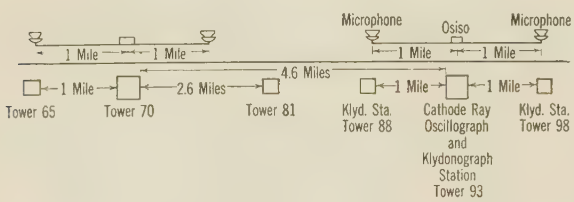

Fig. 7—Layout of Test at Chilhowee, Tenn.

voltage was recorded on either the klydonographs or the oscillographs at the other station, 4½ mi. away.

The storm conditions were observed by the operators, and the following general ideas developed: There were many discharges between clouds apparently directly over, or nearly over, the line without causing any line disturbances of sufficient magnitude to be recorded by either klydonograph or oscillograph. Strokes to earth were observed in the near vicinity of the line without causing any voltage of sufficient magnitude to make either klydonograph or oscillograph records. The particular stroke which gave the record shown in Fig. 13 was observed by one of the operators to be extremely close to the station but later examination did not show the exact place where it struck the earth.

Accomplishments of the First Year's Work. Perhaps the accomplishment of greatest importance resulting from the work during this summer is the demonstration that complete oscillograms of lightning voltages can be secured by the use of the Norinder form of cathode ray oscillograph. The klydonograph record shows that during the test only one voltage of appreciable magnitude occurred on the line at an oscillograph station. A complete oscillogram of this surge was secured; it shows the beginning, the entire wave front, the crest, and the entire duration of the transient.

A second finding of major importance is that any large number of serious overvoltages at any one point on a line during a single season is not to be anticipated. This fact, also, has been indicated by the previous

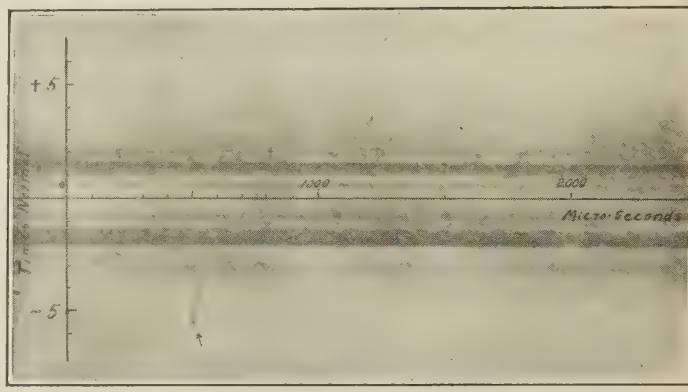

Fig. 13—Oscillogram of Lightning Surge on Transmission Line. 750 Kv.

extensive work with the klydonograph. Its significance in connection with lightning research is that it will be necessary to make a considerable number of installations and to operate them for several years in order to secure records covering the entire range of lightning voltages and operating conditions for various territories.

Need for Coordination of Effort. It is the plan to continue the tests in Tennessee, and probably several more instruments will be installed during the next season at other locations. In course of time, with the proposed program, we could obtain sufficient data to determine the characteristics of lightning waves so that their effect on transmission lines and connected apparatus could be predicted, and improvements in design and construction would result. However, due to the necessarily limited scope of our work or that of any other similar group, the time required to carry out the necessary program would be more than the electrical power industry would care to countenance for an investigation even so vital to the future of power development. When we consider that the annual expenditure of the industry in transmission is of the order of 150 million dollars, it seems clear that there is ample justification for spending the million dollars or so, necessary for adequate lightning research.

The work reported here demonstrates that the means necessary for obtaining a complete solution of the first part of the lightning problem are available. Similar work being conducted by other groups along somewhat different lines will doubtless result in availability of equally satisfactory means. The problem cannot be solved by either the manufacturers or operators working alone nor properly by any small group. The solution requires the financial and technical support

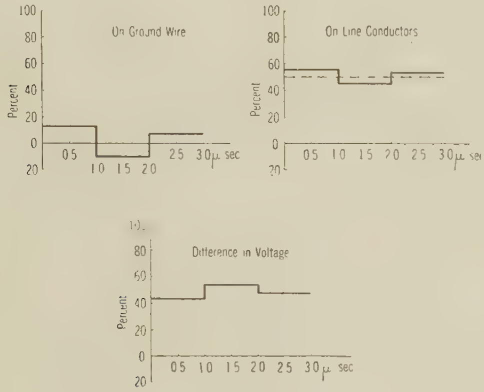

Fig. 19—Induced Voltages on Lines with Ground Wires

Voltages at the towers—based on equal induced voltages on ground and line wires ground resistance $R = 20$ ohms

of the whole industry; and now that the equipment is available, it is necessary only to work out the required organization of effort.

II. Theoretical Discussion of the Propagation of Lightning Surges

(This part of the paper is a rather complete mathe-

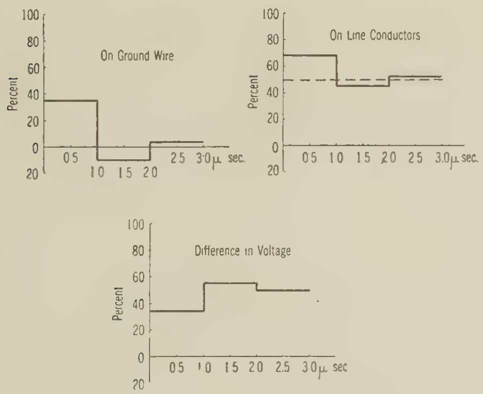

Fig. 20—Induced Voltages on Lines with Ground Wires

Voltages at the tower—based on equal induced voltages on ground and line wires ground resistance $R = 80$ ohms

matical treatment of the theory of traveling waves. Since it is not feasible to abridge a work of this nature, the reader is referred to the complete paper.)

III. The Effect of Ground Resistance of Overhead Ground Wire Protection of Transmission Lines

Overhead Ground Wires as Protection from Induced Waves. Equations (**40**) and (**41**) are of great importance for estimating the actual protection afforded by overhead ground wires to transmission lines when the value of the ground resistance is taken into account. We shall assume, a typical 220-kv. line with two ¾-in. ground wires, that the ground wires when at zero potential would reduce the potential on the transmission lines 50 per cent, and that the spans are 1000 ft. long which would give a wavelength of two microseconds. Then, Fig. 19 shows the potentials of ground wires, line wires, and difference of potential at the tower for ground resistance of 20 ohms.

Figs. 20 and 21 show the same voltage at the tower for resistances of 80 and 200 ohms respectively.

It will be noted that for an interval of two microseconds, the lower resistance gives the lower voltage

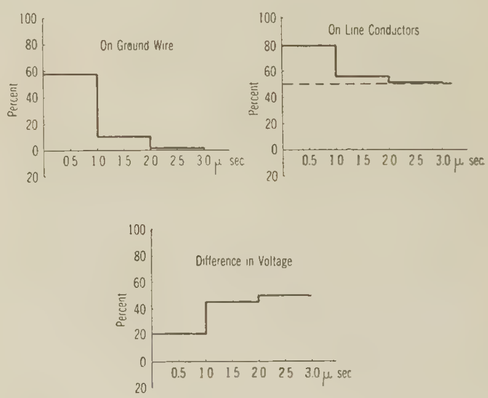

Fig. 21—Induced Voltages on Lines with Ground Wires

Voltages at the towers—based on equal induced voltages on ground and line wires ground resistance $R = 200$ ohms

with respect to ground. The curves of difference of potential between line conductor and ground wires, which is the same as the tower top, seems to favor the higher ground resistance. However, the tendency to arc over an insulator string depends not only on the potential to tower top but also on the potential to ground. Furthermore, the performance of ground wires during direct strokes is more important and the following discussion will show that for direct strokes, a low ground resistance is essential.

Overhead Ground-Wires as Protection against Direct Strokes. A second important practical application for these formulas is for the case of a direct stroke of lightning. We shall first take up the case where the lightning stroke hits the middle of the span.

The phenomenon of lightning discharge has been clarified to a large extent by the experiments of Torok[3]

3. J. J. Torok, *Surge Impulse Breakdown of Air*, Transactions, A. I. E. E., Vol. 47, No. 2, April 1928, p. 349.

in suppressed discharges between sphere-gaps. This phenomenon of suppressed discharge is very frequently observed in thunderstorms.

It is obvious that the intensity of a lightning stroke varies widely, depending upon the height and nature of the cloud, which determines the quantity of charge that can be dissipated in a single stroke. Many strokes never reach the earth, as frequently, due to insufficient energy to support and urge it forward, the progress of the streamer is stopped in mid-air. Others barely reach the earth and this with little energy. Still others, of course, are intense to varying degrees.

In the case of a direct stroke, when the ionized path is complete, there is propagated at once in the transmission line a steep wave-front surge, the crest value of which may last for two or more microseconds depending upon the potential of the cloud and how much of it is drained off over the discharge path.

When the flashover takes place, the cloud is discharged over the ionized path in the form of a surge traveling like any other traveling wave over a conducting path, and since the surge impedance of the path which it must follow decreases progressively as it approaches the earth, the crest of the propagated wave will decrease in potential, progressively, as it approaches earth, so that although the potential of the cloud may be something like 100 million volts, the propagated wave when it reaches a transmission line may not have a crest of more than four or 5 million volts. It may be assumed that when it strikes the transmission line, it has a surge impedance of the same order as that of three transmission line conductors in parallel and since it divides into two waves at this point, the crest value of each of these waves depends upon the surge impedances of the conductors struck and the lightning path, and the voltage of the lightning as it enters the line. This wave may enter the ground wires, the transmission lines, or both, and it will be reflected at the towers in both the earth and other conductors involved. There is no foundation for the opinion that all lightning strokes are so severe that they involve everything in the vicinity. It is likely that ground wires may be struck and conduct the energy away without involving the conductors. Evidence which indicates this has been obtained in klydonograph tests.

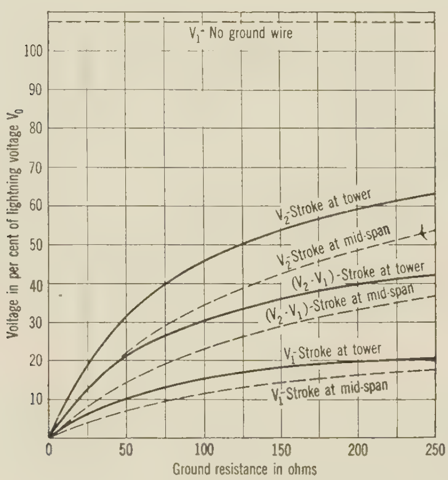

Fig. 24—Surge Voltage on Ground Wire V_2, on Line Wire V_1 and Difference of Voltage as a Function of Ground Resistance in Ohms in Terms of the Lightning Voltage at the Line V_0

Assuming the same typical 200-kv. line chosen above, the voltages at the tower were calculated in terms of the lightning voltage V_0 at the point of contact for various ground resistances and the results plotted in Fig. 24. In addition to curves for V_1 and V_2, a curve of $V_2 - V_1$, or the potential across the insulators, has been plotted. Although based on an assumed surge impedance of lightning path, Z_0 these curves illustrate the importance of low ground resistance in obtaining the highest measure of protection from ground wires against direct strokes. The value given for V_1 with no ground wires was calculated on the basis that the lightning stroke hit only one conductor. This illustrates that a large measure of protection is obtained from ground wires even with a high ground resistance.

Acknowledgment

In preparing this paper we had the assistance of several of our colleagues in the Engineering Department of the Westinghouse Company who took part in the various activities in connection with the lightning investigation.

ELECTRODEPOSITION AND CORROSION

The variety of articles to which the process of repair by electrodeposition can be applied has extended rapidly within recent years. This method of repair was employed extensively during the war, and has been since developed to a considerable degree in America. The experience gained by increased practise has certainly resulted in the product of a better repaired article. But it must be remembered that there can be no homogeneity in the metal of the repaired article. It is for the engineer to decide in each particular case whether the absence of homogeneity, with the consequent difference between physical and mechanical properties, is harmful to his purposes. As regards protection by electrodeposition, it should be remembered that, in so far as iron is concerned, zinc is the only really protective covering that is commercially applicable. Cadmium will protect iron almost as well as zinc, but the cost of cadmium restricts its use. Chromium does not protect iron from corrosion, though the deposit of chromium can be useful for other purposes.—*World Power.*

Abridgment of

Power Factor and Dielectric Constant in Viscous Dielectrics

BY DONALD W. KITCHIN*

Associate, A. I. E. E.

Synopsis.—This paper gives the results of a study of the peculiar variation with temperature and frequency of the dielectric constant and power factor of rosin, rosin oil, and castor oil. It includes data showing, at several frequencies, the relation of dielectric constant and power factor to the composition of vulcanized rubber.

Electrical double refraction in rosin at different frequencies and temperatures is discussed in relation to its behavior as a dielectric. It is shown that the viscosity is a decisive factor controlling both the electrical and optical behavior The facts are important in themselves but it is possible to interpret them by a modern physical theory, the Debye[1] dipole theory, which it is believed has not hitherto been applied to commercial dielectrics. On this theory, the anomalous change of dielectric constant and power factor with temperature and frequency is attributed not to impurities or heterogeneity of structure but to molecules containing electric doublets which try to orient themselves in an electric field. The rotation of the dipole molecules in a viscous medium gives rise to frictional heat loss expressed as power factor, and also to a contribution to the dielectric constant which vanishes when the dipoles are prevented from responding by too great viscosity or too high frequency.

For the sake of intelligibility, first an outline of the dipole theory is presented and then the experimental results are discussed on the basis of that theory.

* * * * *

I. Introduction

THE behavior of dielectrics in alternating fields has been the subject of considerable experimental and theoretical investigation. The purpose of this paper is to introduce the concept of the orientation of polar molecules as a basis of explanation of some aspects of dielectric behavior. The typical behavior is shown by rosin oil at one million cycles. (See Fig. 2, curves P_1 and D_1). It is readily seen that the observed temperature variation of dielectric constant and power factor cannot be explained by changes in density and leakage current. An attempt is made in this paper to explain this behavior by the Debye[1] dipole theory. Since the dipole theory of dielectrics may not be familiar to all who are interested in insulating materials an outline is given here. For a full presentation the treatise of Debye[1] should be consulted.

II. Molecular Behavior in Electric Fields

The electron theory of the dielectric constant is sufficiently familiar to require no discussion here other than to point out that the motion of the displacement electrons in following an alternating field may be considered to take place without lag and with no dissipation of energy.

1. Dipoles. There exist substances whose molecules are polarized even in the unstressed state due to their configuration. These molecules contain fixed electric doublets or dipoles which tend to turn them into line with an electric field. This tendency is opposed by the thermal motion, so that the effect of an ordinary field is a relatively small one which decreases with rising temperature.

For a dipole to respond to an electric field it is necessary for the molecule as a whole to turn, and any factor which affects the ease of turning controls the dielectric constant. The sudden and pronounced drop in ϵ when a dipole liquid freezes exemplifies this effect. If instead of freezing to a crystalline solid, the dipole liquid exhibits a great increase in viscosity on being cooled, the change in ϵ is gradual instead of sharp, and in addition, ϵ depends on the applied frequency, for while the dipoles may be so sluggish at a certain temperature that they cannot respond to a given high frequency, still they are able to follow a slower field and contribute to ϵ. The applied frequency therefore determines the region of viscosity, and consequently of temperature, where the drop in ϵ occurs. Rosin, rosin oil, castor oil, and glycerine (see Bock[5]) furnish good examples of this behavior.

2. Dipole Power Factor. The motion of the dipole molecules turning in a viscous environment gives rise to frictional losses, so that some of the energy of the field is dissipated in the form of heat. The magnitude of the resulting power factor is determined by two factors, namely, the amount of motion, of which the dielectric constant is a function, and the viscosity opposing the motion. At temperatures where the viscosity is low, the dipole power factor (so called to distinguish it from that due to leakage) is small. On the other hand, at viscosities practically great enough to prevent orientation, the power factor is again small. The maximum occurs in the intermediate region of temperature where the resultant of motion and high viscosity is greatest. This is the region where ϵ decreases with falling temperature.

*Research Laboratory, Simplex Wire & Cable Co., Boston, Mass.

1. For all references see Bibliography.

Note: An English text "Polar Molecules" by Debye is announced by the Chemical Catalog Co.)

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

III. Discussion of Experimental Results

Transil oil, tested at one million cycles between 70 deg. and 160 deg. fahr., showed negligible power factor. Light amber petrolatum showed a gradual decrease in power factor from 0.16 per cent at 74 deg. to 0.03 per cent at 210 deg. As expected the dielectric constant decreased

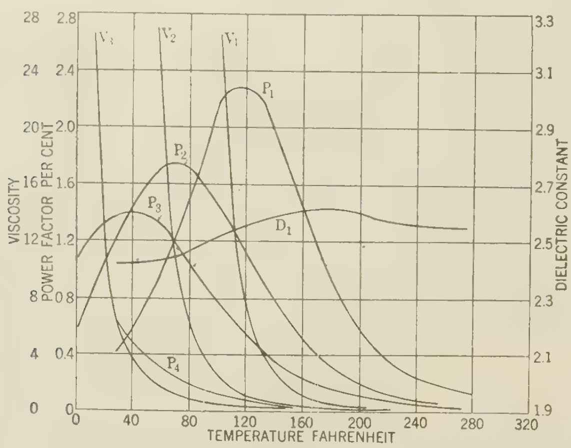

Fig. 2—Curves showing Effect of Dilution on Position of Power-Factor Maximum at 1 Million Cycles

D = dielectric constant
P = per cent power factor
V = viscosity Stormer—minutes per 100 turns

Subscripts refer to composition of mixtures:
1 100 per cent rosin oil (containing 50 per cent rosin)
2 80 per cent rosin oil 20 per cent Transil oil
3 50 per cent rosin oil 50 per cent Transil oil
4 20 per cent rosin oil 80 per cent Transil oil

with rising temperature. The peculiar behavior of a commercial rosin oil (50 per cent rosin, 50 per cent mineral oil) gave the first hint of an explanation of the anomalous change in power factor and dielectric constant. Inspection of the viscosity curve shows that the power factor maximum and the drop in ϵ occurs in a temperature region where the viscosity increase is very rapid. This suggests the idea that the power factor and a part of ϵ depend on some mode of motion which is greatly influenced by the viscosity of the medium. Dipole orientation discussed above readily accounts for this behavior.

1. Effect of Dilution. If the behavior was due to some chemical change in the dissolved rosin rather than to the effect of viscosity, dilution with a neutral oil (*i. e.*, one of negligible power factor) like Transil oil, should merely decrease the power factor without shifting the position of the maximum. If, on the other hand, the dipole explanation is correct, dilution with Transil oil to decrease the viscosity should shift both the power factor and dielectric constant maxima for constant frequency to lower temperatures. Fig. 2 shows that the curves for one million cycles shift in the predicted manner. It is readily seen that an enormous increase of viscosity is necessary to cut down the orientation sufficiently to cause a large power factor decrease. This is to be expected, since the great increase in dipole friction with rising viscosity partly counteracts the effect of diminishing orientation. The same reasoning explains the fact that the dielectric constant always starts to fall at lower viscosity, *i. e.*, higher temperature, than where the power factor maximum is reached.

Substitution of the more viscous Nujol for Transil oil in a 50 per cent mixture, with rosin oil shifted the position of the power factor maximum from 40 deg. to 55 deg. fahr. This is additional proof of the orientation theory, since the mere substitution of one neutral oil for another should have no chemical effect on the rosin content. Replacing the Transil oil with 50 per cent of heavy cylinder oil caused a still greater shift to 75 deg.

An interesting fact was shown by the behavior of a mix of 50 per cent rosin oil in 140 deg. paraffin. At 122 deg. it was apparently solid, yet the power factor curve showed no break. The explanation lies in the fact that the apparent consistency is not a true indication of the actual environment opposing the motion of the dipole molecules. In the stiff, salve-like mixture there is a distributed liquid component in which the dipoles turn freely until this liquid component becomes very viscous.

2. Effect of Change of Frequency. Fig. 3 shows the results at 60 cycles, 1 million, and 10 million cycles, obtained with Hercules Wood Rosin *F*. The

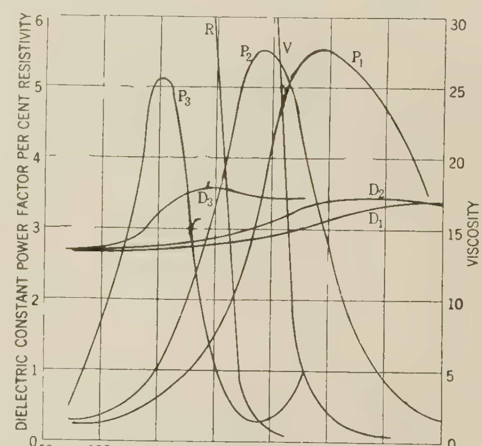

Fig. 3—Curves showing Behavior of Wood Rosin at Different Frequencies

V viscosity Stormer in minutes per 100 turns
R resistivity in ohms $\times 10^{12}$ per cu. cm.
P per cent power factor
D dielectric constant

Subscripts refer to frequency:
(1) 10 million cycles
(2) 1 million cycles
(3) 60 cycles

two higher frequency curves and the viscosity curve are plotted from data obtained by the writer; the data for the 60-cycle curve and the resistivity curve were kindly furnished by the Hercules Powder Co.

a. Dielectric Constant of Rosin vs. Temperature and Frequency. The course of the dielectric constant curves is in good agreement with the theory. At 80 deg. fahr.,

ϵ is the same for all three frequencies. This value $\epsilon = 2.68$ is due to the displacement electrons alone, as shown by the fact that the power factor has dropped to negligible values. The viscosity of the rosin at this point is so enormous that even the slighest dipole motion would give rise to high frictional losses, so that we may be sure that the contribution of dipole motion to ϵ is practically nil. Thus, when the dipoles are practically fixed—*e. g.*, down to 60 cycles,—ϵ is independent of frequency. On the other hand, the ϵ curves again converge on the high temperature side, because there the viscosity is very low, resulting in a characteristic frequency high compared to the three applied frequencies, and the dipole response is complete. At 180 deg. ϵ for 60 cycles reaches a maximum, while it is still low for the two radio frequencies. At this point, the dipoles respond fully to the 60-cycle field, but are too sluggish to follow the higher frequency fields. Above this temperature ϵ for 60 cycles drops because while the dipole response no longer increases, the density decreases. At 260 deg. and at about 310 deg., the dipole response to the 1 and 10 million cycle fields is complete.

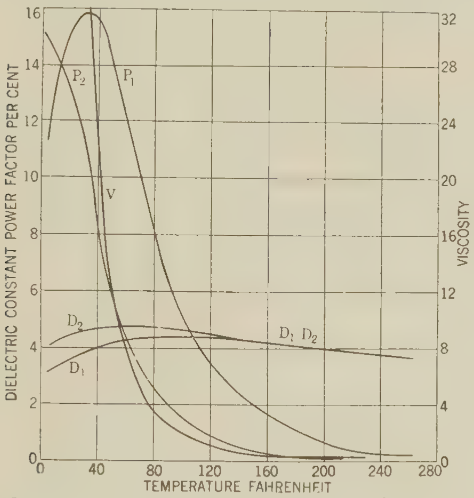

FIG. 4—CURVES SHOWING BEHAVIOR OF CASTOR OIL AT 2 FREQUENCIES

V viscosity Stormer in minutes per 100 turns
P per cent power factor
D · dielectric constant
Subscripts refer to frequency:
1 10.9 million cycles
2 1.415 million cycles

b. Relation of Spacing and Width of Power Factor Curves. The comparative widths of the curves of power factor and dielectric constant (Fig. 3) and the way they are spaced with respect to temperature are good qualitative evidence of the correctness of the orientation theory. On the orientation theory the curves for equal multiples of frequency would be of equal width and spaced at equal temperature intervals, provided the viscosity changed exponentially with temperature But inspection of the viscosity curve for rosin shows that the viscosity change is more rapid.

The result is that the 60-cycle curve, being in a region of viscosity increase which is much more rapid than that in the higher temperature radio frequency region, is narrower than the 1 million-cycle curve, which in turn is narrower than the 10 million-cycle curve. Also, the 1 and 10 million-cycle curves are farther apart relative to the frequency difference than the 60-cycle and 1 million-cycle curves. The viscosities corresponding to 1 and 10 million-cycle power factor maxima are approximately in the ratio 10 to 1 as they should be.

c. Tests on Castor Oil. In order that all the tests might not be confined to rosin-containing materials, similar tests were made on a sample of refined castor oil. The curves are shown in Fig. 4. It will be noted that very high frequency is required to bring the power factor maximum above 0 deg. fahr.

3. Optical Evidence of Orientation. Some results of optical tests on rosin are included because of the additional support they give to the orientation theory. The work was done with Professor Hans Müller of the Massachusetts Institute of Technology, and is treated more fully in a joint paper.[11]

The phenomenon of electrical double refraction, called the Kerr[12] effect, is well known. Many materials become double refracting in a strong electrostatic field.

Non-dipole liquids show some Kerr effect, but polar liquids show it much more strongly. Since this effect depends upon dipole orientation, the time required for the effect to disappear after sudden discharge should equal the relaxation time already defined for electrical polarization. Then, by reasoning similar to that which applies to the change of dielectric constant, the effect should fail to appear in an alternating field of frequency too high for the dipoles to follow. This prediction was confirmed by the behavior of rosin. At room temperature, solid rosin showed a good Kerr effect with a static field of 10,000 volts, but none whatever with a 60-cycle field even though the stress was increased to 75,000 volts.

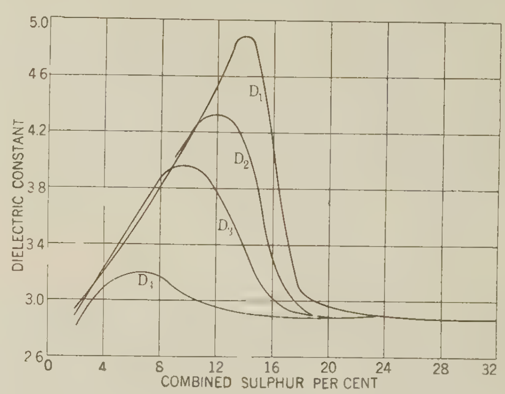

FIG. 5—CURVES SHOWING DIELECTRIC CONSTANT *vs.* PER CENT COMBINED SULPHUR AT 4 FREQUENCIES

Subscripts refer to frequency:
1 0 cycles, *i. e.*, static stress
2 60 cycles
3 1000 cycles
4 380,000 cycles

The sudden discharge was produced by shorting the cell. A very long relaxation time for the optical effect was noted at room temperature. After discharge, it took least 30 seconds for the image of the slit to disappear. The threshold temperature for the appearance of the effect at 60 cycles was found to be about 100 deg. The difficulties of observation precluded an accurate determination of the threshold temperature at 1.5 million cycles, but the Kerr effect could be observed unmistakably above 240 deg. which is in approximately the correct region. Thus, the optical behavior of rosin at different applied frequencies gives strong additional support to the orientation theory advanced to explain anomalous power factor and dielectric constant changes.

4. Electrical Behavior of Rubber-Sulfur Compounds. Electrical tests at various frequencies on samples of vulcanized rubber containing different amounts of combined sulphur show very interesting features which may be related to the dipole theory.

Figs. 5 and 6 show that the positions of the maxima

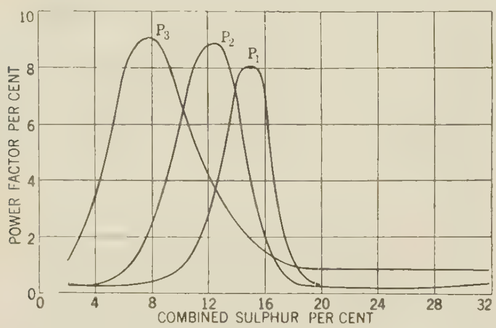

Fig. 6—Curves showing Power Factor *vs.* Per Cent Combined Sulphur at 3 Frequencies

Subscripts refer to frequency:
1 60 cycles
2 1000 cycles
3 380,000 cycles

can be shifted over a wide range of composition by changing the test frequency. The application of the orientation hypothesis to rubber is only tentative and considerable critical experimental work would be needed to place it on as firm a basis as in the case of viscous liquids.

Conclusions

1. The peculiar temperature variation of dielectric constant and power factor at different frequencies of rosin, rosin oil, and castor oil, and the anomalous change in electric double refraction of rosin have been shown to be functions of the viscosity.

2. The influence of viscosity on both the electrical and optical properties has been explained on the Debye theory of dipole orientation.

3. The electrical behavior of vulcanized rubber samples of various compositions suggests the presence of dipole molecules.

4. Very accurate measurements on viscous, dipole materials of high purity would be of great value in checking and extending the theory.

The results given in this paper are believed to be of value both to electrical engineers and to physicists. It is hoped that they will help to interest practical students of dielectrics in a physical theory which hitherto has been tested for the most part at frequencies and on materials remote from practical purposes.

Bibliography

1. P. Debye, "Theorie der Elektrischen und Magnetischen Molekular-eigenschaften," in *Marx. Handbuch der Radiologie*, Vol. VI, Leipzig, 1925.

2. Maxwell, "Electricity and Magnetism," Vol. I, p. 328.
Wagner, *Ann. d. Physik*, **40**, 817, 833 (1913); *Archiv. f. Elektrotechnik*, **2**, 371 (1914).
Schweidler, *Ann. d. Physik*, **24**, 742 (1907).
Pellat, Ann. Chimie et Phys., **18**, 150 (1899).

3. Ratnowsky, *Berichte d. Deutschen Phys. Ges.*, **15**, 497 (1913).

4. Isnardi, *Phys. Zeitschrift*, **22**, 230 (1921); *Zeitschrift f. Physik*, **9**, 153 (1922).

5. Bock, *Zeitschrift f. Physik*, **31**, 534 (1925).

6. P. Drude, *Zeit. f. Phys. Chem.*, **23**, 267 (1897).

7. Nichols and Tear, *Phys. Review*, **21**, 587 (1923).

8. Hochstäder, *Elektrotech. Zeitschrift*, **17**, 575 (1922).

9. Dunsheath, *Inst. Elec. Eng. Jour.*, January 1926

10. Curtis, McPherson, and Scott, Scientific Papers of the Bureau of Standards No. 560.

11. Kitchin and Müller, *Physical Review*, December 1928.

12. Kerr, *Phil. Mag.*, (4) **50**, 337, 446 (1875).

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

EXCERPTS FROM LETTERS OF APPRECIATION

February 13, 1928.

I am enclosing herewith a check for $49.50 as a contribution to the Employment Service for its use by me in securing my present position. I hope that this may show to some extent my appreciation for the excellent service it has rendered me.

February 10, 1928.

The service rendered by the Bureau is excellent, and I heartily thank you for the assistance you gave me in obtaining the position at a time when general business conditions were very slack.

December 1, 1928.

We wish to express our appreciation for the helpful cooperation of the Engineering Societies Employment Service and thank you for your personal interest.

(signed) Plant Manager

November 10, 1928.

We wish to express our appreciation of your cooperation in securing the services of this engineer, as he and several other men interviewed, turned out to be the very highest caliber and we hope and expect to use your service to a larger extent in the future.

July 1, 1928.

I might say that I have been very much impressed by the excellent service rendered by your office, and a contribution will be forthcoming very shortly.

Abridgment of

No-Load Induction Motor Core Losses

BY T. SPOONER[1] and C. W. KINCAID[1]

Member, A. I. E. E. Associate, A. I. E. E.

Synopsis.—A detailed method of calculating the no-load core losses of induction motors is presented, whereby each loss component is estimated separately. There is included a discussion of extra losses due to imperfection in workmanship. Calculated and test results on a few commercial machines are given as an indication of the reliability of this method.

In general, the simplest and most reliable method of predicting the core losses in a rotating machine of new design is to estimate them from the test results on machines of similar type. This is the method ordinarily used by experienced designers. In some cases, however, this procedure is not adequate. For instance, if in a certain type of machine the core losses are higher than anticipated, a more detailed analysis is necessary, or if a machine is proposed which has certain radically different features from any existing machine, a calculation of losses based on fundamentals is essential if these losses are to be properly estimated. It is our purpose here to consider all of the important factors which produce no-load core losses in induction motors and similar types of apparatus and to give a method of calculating these losses.

Types of Loss

This discussion will be confined to induction motors, but it will be obvious that the methods can be applied to other types of machines in which both the stator and rotor are slotted and in which the air-gap flux has approximately a sine-wave distribution.

For the purpose of calculation, induction motor losses will be segregated into the following components:

1. Fundamental frequency losses.
    a. Stator core
    b. Stator tooth
2. Pulsation losses.
    a. Surface (stator and rotor)
    b. Tooth pulsation (stator and rotor)
    c. Copper eddy (stator and rotor)
3. Illegitimate losses.

The fundamental frequency losses are those due to the hysteresis and eddy-current losses in the core material corresponding to the applied frequency, and are assumed to be the same as would occur under alternating flux as in a transformer core for the same maximum induction. This assumption may be open to question so far as the core flux is concerned, since this flux has an elliptical, rather than an alternating variation but the simpler assumption with corrections, if necessary, for the elliptical field seems to give satisfactory results. It is assumed that the frequency of the main flux in the rotor is so low that the losses are negligible.

The pulsation losses consist first of the surface losses which are those hysteresis and eddy losses occurring just below the surface of the tooth tops due to the passage of the slots of the other member and are practically the same as the well-known pole-face losses.

The tooth pulsation losses are those caused by the high-frequency pulsations of flux extending the whole length of the teeth and a little way into the core due to the reluctance changes in the air-gap as the slots of one member pass the teeth of the other. The distinction between surface and tooth pulsation losses is somewhat arbitrary but seems to work fairly well.

The no-load copper eddy-current losses are not, of course, really core losses, but appear as such by the ordinary methods of test. They are due to the high-frequency slot-leakage fluxes as the result of the momentary changes in the saturation of the teeth. They have both tangential and radial components.

The illegitimate losses are those caused by punching strains in the tooth iron, short-circuited laminations due to burrs and slot filing, bending strains in the iron sheets, and finally to leakage fluxes into the frames, end-bells, and other solid members.

Fundamental-Frequency Stator Core Losses

The fundamental frequency losses in the stator core are to be calculated in the usual way from loss curves on the particular type of material to be used in the machine if the ratio of inside to outside radius of core is large or if there is a considerable number of poles corrections to be made for non-uniformity of flux according to the method described by Alger and Eksergian.[2]

Fundamental Frequency Stator Tooth Losses

The stator teeth of an induction motor are subjected to approximately a sine-wave variation of fundamental frequency flux on which generally is superposed a high frequency ripple corresponding to the number of slots in the rotor. It has often been assumed that these high-frequency pulsations tend to reduce the fundamental frequency hysteresis losses. It has been shown,[3]

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1. Both of Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Presented at Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

2. *Induction Motor Core Losses*, P. L. Alger and R. Eksergian, Jl. A. I. E. E., October 1920, p. 906.

however, that this is not the case and that the fundamental frequency hysteresis losses are proportional to the maximum flux density, whether or not the high-frequency pulsations are superposed.

Referring to Fig. 5, B is the maximum magnetic flux density in the teeth as ordinarily assumed and B_m is the actual maximum flux density. It is necessary, therefore, to calculate the magnitude of these high-

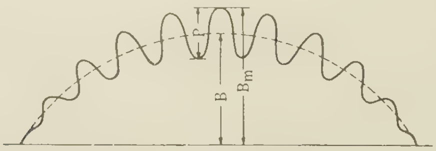

FIG. 5—SHOWING TOOTH FLUX VARIATIONS FOR INDUCTION MOTOR

frequency flux pulsations in the teeth. This can be done by means of the formulas given in a previous A. I. E. E. paper.[4]

SURFACE LOSSES

The method of calculating surface losses has been described in the A. I. E. E. TRANSACTIONS for 1924, p. 252.

TOOTH PULSATION LOSSES

The method of calculating the magnitude of tooth pulsations has been given in a previous paper.[3] Corrections to the calculated pulsation P may be made according to Fig. 9, or assuming a straight line relation between induction and percentage pulsation P as effected by saturation the following formula may be used instead of Fig. 9.

$$P_S = P\left(1.6 - \frac{B}{100}\right) \tag{9}$$

Fig. 9 and formula (9) are based on theoretical considerations only. Experimental results on actual machines seem to indicate that the following formula more nearly fits the facts for large induction motors.

$$P_S = P\left(1.3 - \frac{B}{165}\right) \tag{10}$$

These corrections to P are based upon the assumption that the losses vary as the square of the pulsation amplitude. Of course the effect of saturation increases as the pulsations follow up along the fundamental flux curve toward the maximum value. These saturation effects have been integrated for the whole fundamental wave.

The variables for calculating pulsation losses are as follows: f_{st} or f_{rt} as above, where f_{st}, for instance, corresponds to the number of stator teeth, but is used to calculate the rotor tooth pulsation losses.

B_m, the maximum tooth induction, which for the stator teeth may be taken as the same as used in the calculation of the fundamental frequency tooth losses, or, more accurately, should be recalculated using curve 9 or formula (9) or (10). In the latter case:

$$B_m = B\left(1 + \frac{P_S}{200}\right) \tag{11}$$

where B is the net tooth induction ⅓ from the narrowest section, P_S is the percentage pulsation as corrected for saturation.

$P\,B_m$ the product of B_m and P_S. The tooth pulsation losses for a wound rotor per net, cu. in. of core material are:

$$W_{rtf} = \underset{\text{(Hysteresis)}}{(10^{-3} f_{st}\, K_{Bm}\, K_P)} + \underset{\text{(Eddy)}}{(K_{PBm}\, K_{fst})} \text{ watts} \tag{12}$$

The K factors are obtained from Fig. 10, K_{Bm} corresponds to the rotor tooth B_m as obtained from formula (11). K_P is the rotor pulsation constant corresponding to the percentage pulsation as corrected for saturation.

The hysteresis component of this formula was obtained from a fundamental study of the losses of displaced hysteresis loops. The eddy-current component was obtained by many tests on an experimental machine supplied with various slot combinations.

The stator tooth pulsation losses are calculated as follows when they are appreciable:

$$W_{stf} = (10^{-3} f_{rt}\, K_{Bm}\, K_P) + (K_{PBm}\, K_{frt}) \text{ watts} \tag{13}$$

If the machine has a squirrel-cage rotor instead of a

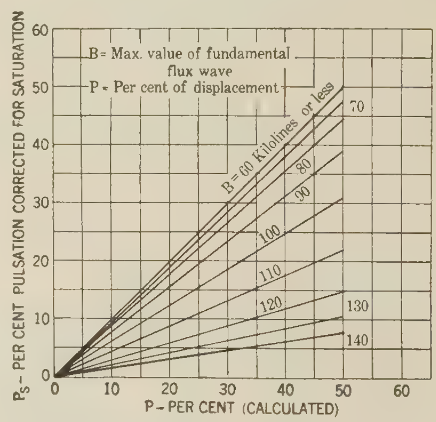

FIG. 9—TOOTH-SATURATION CORRECTION CURVES FOR CALCULATING PULSATION LOSSES

wound rotor, the conditions are different. In this case, due to the short-circuited turns around the teeth no very appreciable high-frequency flux can flow. Thus the tooth-frequency losses in the rotor teeth will be negligible. As pointed out by Alger and Weichsel[5] some years ago, however, the high-frequency currents which flow in the rotor bars produce a corresponding m. m. f. which acts on the stator teeth to produce high-frequency pulsations in these teeth which may be responsible for very considerable losses.

The magnitude of the stator tooth pulsations as a

3. "Effect of Superposed Alternating Field on Apparent Magnetic Permeability and Hysteresis Loss," T. Spooner, *Phys. Rev.*, Vol. 25, Sept. 2, 1925, page 527.

4. *Tooth Pulsations in Rotating Machines*, T. Spooner, A. I. E. E. TRANS., Vol. 43, 1924, p. 252.

5. A. I. E. E. TRANS., Vol. 44, 1925, p. 160.

result of the high-frequency rotor currents would be difficult to calculate accurately. Therefore, in the case of squirrel-cage motors, the expedient has been adopted of calculating the rotor tooth pulsation percentages as if there were no squirrel-cage windings, then assuming that these are the percentage pulsations which actually occur in the stator teeth due to the rotor high-frequency currents. The rotor tooth pulsations and therefore the pulsation losses are assumed negligible and the stator tooth pulsation losses calculated from formula (**13**) assuming P_s equal to the calculated rotor

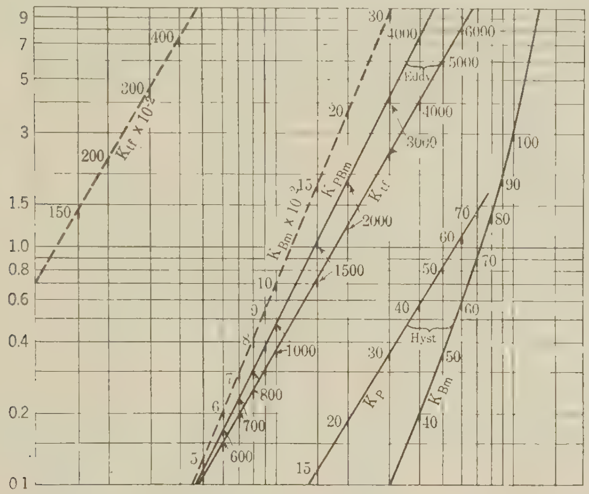

Fig. 10—Curves for Calculating Tooth Pulsation Losses

Note: All inductions and vol. are based on net section assuming a space factor of 90 per cent.

$W_{tf} = (10^{-3} f_t K_{B_m} K_P) + (K_{PB_m} K_{ft})$

W_{tf} = Tooth frequency loss in watts per cu. in.

$f t$ = Tooth frequency

K_{B_m} = Max. tooth induction factor (B_m is in kilolines per sq. in.)

K_P = Tooth pulsation factor (P is in per cent of B_m)

K_{PB_m} = Factor for % tooth pulsation and max. induction product

K_{ft} = Tooth frequency factor

$$f t = \frac{\sim \times \text{no. of teeth}}{\text{pairs of poles}} = \frac{\text{rev. per min.} \times \text{no. of teeth}}{60}$$

For rotor $f t$ use no. of stator teeth

For stator $f t$ use no. of rotor teeth

tooth pulsation percentage. When the number of stator and rotor teeth is not very different, this is a fairly reliable assumption.

Copper Eddy Losses

The cause and nature of these losses have been discussed in a previous paper.[6] They become of appreciable magnitude only at quite high tooth flux densities. These losses are caused by high-frequency slot-leakage fluxes which occur due to the saturation of the teeth. In general, since the conductors are small and the teeth are less saturated, the stator no-load copper eddy losses are negligible, but the rotor copper eddy losses are often appreciable both for squirrel-cage and wound-rotor induction motors.

6. *No-load Copper Eddy-Current Losses*, T. Spooner, A. I. E. E. Trans., Vol. XLV, 1926, p. 231.

Illegitimate Losses

These losses have already been mentioned previously, and are losses in addition to those which would occur in annealed unsaturated cores with perfect insulation between laminations. Due to their variability they are difficult to estimate and should, so far as possible, be eliminated. They are one of the major causes of differences between calculated and test results.

One of the most common types of extra losses in rotating machines appears as the result of eddy currents caused by short-circuited laminations. Short-circuited laminations may be produced when types of construction are used such that the punchings are wedged onto dovetails or keyways, or are forced on the shaft. This connects together electrically the back edges of the laminations. Now if the teeth contain burrs or if the slots are filed, the laminations become short-circuited and in this case there may result very considerably increased fundamental frequency core losses.

For motors with narrow teeth, there may be considerably increased losses due to punching strains. At an induction of 65 kilolines per sq. in., the losses are increased by an amount which can be calculated approximately by increasing the standard loss by a factor

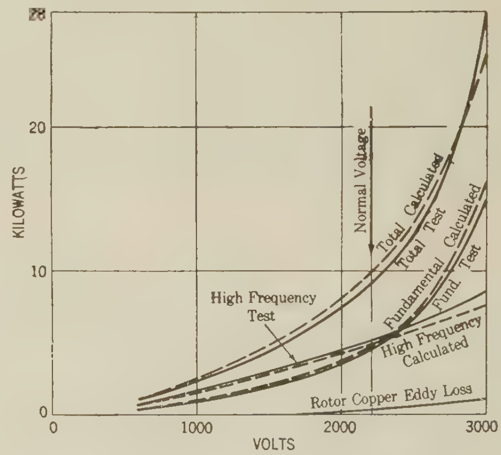

Fig. 12—Wound Rotor Induction Motor

Comparison of calculated and test no-load core losses

equal to 14 divided by the mean tooth width in inches; namely:

$$W_{cor} = W_{std}\left(1 + \frac{0.14}{t}\right) \qquad (16)$$

At 100 kilolines the correction is perhaps not over one-half this value and at very high flux densities it is very small. If the stampings are annealed after punching there is no such correction.

If the punchings are not flat, bending strains may appear, increasing the losses at medium inductions. Above 100 kilolines there would be very little effect due to this cause.

If a motor is operated at very high core inductions leakage flux into the frames, end-bells, and other solid

members may cause the losses to go up very rapidly with voltage. In a properly designed machine operated at normal voltage this should be a small factor.

Experimental Methods of Separating Losses

The several different kinds of loss which must be considered to obtain the total have been described and it would be very convenient if each one of these several losses could be tested alone or separated from the others. This ideal will hardly be realized, but tests which give a separation of losses with respect to the frequency which causes them can be made.

TABLE I
WOUND-ROTOR INDUCTION MOTORS
COMPARISON OF TESTED LINE FREQUENCY AND SLOT FREQUENCY LOSSES TO CALCULATED VALUES

	Per cent normal voltage	Line-freq. loss		High-freq. loss		Total loss	
		Test	Calc.	Test	Calc.	Test	Calc.
60-cycle...	56.8	1.00	1.36	2.20	2.33	3.20	3.69
12-pole....	79.5	2.10	2.32	3.70	3.55	5.80	5.87
	102.2	4.35	4.83	5.35	5.38	9.70	10.21
	125.0	9.80	9.90	7.40	7.20	17.20	17.10
		0.50	0.50	1.05	0.86	1.55	1.36
60-cycle...	56.8	0.96	1.06	1.94	1.98	2.90	3.04
16-pole....	79.5	1.98	1.97	2.82	3.20	4.80	5.17
	102.2	3.53	3.35	3.57	4.38	7.10	7.73
	125.0	6.03	6.41	4.17	5.83	10.20	12.24
		2.06	2.11	1.65	3.60	3.71	5.71
60-cycle...	56.8	4.67	4.55	6.13	8.35	10.90	12.90
24-pole....	79.5	8.67	8.70	11.63	13.18	20.30	21.89
	102.2	14.65	14.80	16.35	18.55	31.00	33.36
	113.7	19.55	20.15	19.85	21.59	39.40	41.74
	45.5	1.40	1.14	1.50	1.33	2.90	2.47
25-cycle...	60.6	2.31	1.82	2.50	2.11	3.81	3.93
10-pole....	75.8	3.40	2.75	3.50	3.00	6.90	5.75
	90.9	4.80	4.05	4.60	4.06	9.40	8.11
	106.0	7.00	6.21	5.70	5.18	12.70	11.39
	121.1	11.10	10.50	6.60	6.89	17.70	17.39

Checks on other machines, which were not specially tested, show the same general agreement in the total losses.

One method which is applicable only to wound rotor motors was described by R. Richter in the *Elektrotech. Zeitsch.*, January 6, 1921.

This is the method that has been used in separating the losses in some of the motors shown in the curves.

Another method which is applicable to all types of machines is described by Messrs. Alger and Eksergian.[7] The fundamental idea is covered by their statement: "It is a general principle that whenever any cyclic variations in the permeance of a magnetic circuit are caused by the relative movement of parts of the circuit all the losses caused by this variation are supplied by the mechanical agency causing the motion."

Applied to the induction motor, this means that the tooth frequency losses are supplied by torque in the rotor. Now, the rotor can only receive power by running slower than the rotating field, *i. e.*, slipping, and by hysteresis loss in the rotor core and teeth. The slip can be measured very accurately by several means so that this portion of the rotor torque is known, but the hysteresis losses in the rotor core and teeth must be calculated. The hysteresis loss effect is as though it were at line frequency.

Another method requiring a driving motor and also accurate meter readings makes use of the step in the stator loss curve which occurs when the rotor is driven through synchronism. This has been described by Messrs. Alger and Eksergian[8] and by Messrs. Spooner and Kinnard.[9]

TABLE II
WOUND-ROTOR INDUCTION MOTORS
COMPARISON OF TESTED AND CALCULATED TOTAL LOSS VALUES

Per cent normal volts	60 cycles 10 poles		25 cycles 4 poles		25 cycles 8 poles		25 cycles 10 poles		25 cycles 34 poles	
	Test	Calc.	Test	Calc.	Test	Calc.	Test	Calc.	Test	Calc.
34.1	2.87	3.50	1.03	12.2	4.8	5.6				
45.5	4.89	5.46	1.68	20.2	11.8	9.9			7.4	6.7
56.8	6.69	7.22	2.37	30.8	16.8	16.1	68.0	50.4	15.1	13.4
68.2	9.55	10.36	4.16	45.3	28.4	26.0	88.6	86.2	24.6	21.7
79.5	12.70	13.36	6.22	61.4	38.0	38.1	137.0	141.	34.9	31.9
91.0	16.58	16.64	8.00	80.6	49.5	49.7	175.0	185.	46.3	44.4
100.0	20.26	19.85	10.66	10.60	63.8	64.2	204.0	222.	53.8	52.8
113.7	25.40	26.70	12.35	12.33	81.2	83.9	258.0	272.	57.9	59.6
125.0	32.00	32.46	14.10	14.67	99.0	98.2	345.0	342.	68.1	75.3

TABLE III
SQUIRREL-CAGE INDUCTION MOTORS
COMPARISON OF TESTED AND CALCULATED CORE LOSSES AT NORMAL VOLTAGE

Hp.	Freq.	Line freq. loss		High freq. loss		Total loss	
		Test	Calc.	Test	Calc.	Test	Calc.
250	60	1.98	1.87	1.72	1.22	3.70	3.09
500	60	6.04	6.02	3.93	3.14	9.97	9.16
175	40	1.08	1.07	0.95	0.64	2.03	1.71
125	40	0.82	1.15	1.30	1.27	2.12	2.42
225	40	1.83	1.96	2.09	1.53	3.92	3.49

This method may be used on wound-rotor motors but on squirrel-cage motors the torque is so large that it is very hard to get satisfactory readings unless the frequency and speed are very accurately controlled.

Test Results

Several large wound-rotor motors have been tested according to the first method for loss separation and the losses have been compared with the losses calculated by the above described methods. The curve for

7. Alger and Eksergian, *loc. cit.*
8. Alger and Eksergian, *loc. cit.*
9. *Surface Iron Losses with Reference to Laminated Materials*, A. I. E. E. Trans., Vol. XLXXX, 1924, p. 252.

the line-frequency losses was obtained from one of the tested machines and checks well with the loss curve for the grade of iron used. Table I shows the fundamental and the pulsation-frequency losses calculated separately. Table II gives data for other machines without separation of losses. Fig. 12 shows the results graphically for one of these machines.

In Table III are presented some data on squirrel-cage motors. These checks are not as good as for the wound-rotor machines partly because of the greater difficulties of test. These results were obtained about three years ago. The calculated pulsation losses are probably low because no account was taken of copper eddy-current losses.

Conclusions

The above described method of calculating no-load induction-motor core losses appears to be rather tedious and complicated and as compared with the older empirical methods this is the case. However, by the use of a suitably prepared schedule the time may be greatly shortened. The time for such a calculation, provided all of the factors which have to be calculated for other purposes are available, is from 30 to 40 min. This is not excessive when dealing with a radically new design or with a type of machine which has given trouble due to high losses. It is hoped that this paper will stimulate discussion and will bring forth other methods for making these detailed calculations.

Abridgment of

The Predominating Influence of Moisture and Electrolytic Material Upon Textiles as Insulators

BY R. R. WILLIAMS[1] and E. J. MURPHY[1]
Non-member Non-member

Synopsis.—*The insulating qualities of textiles vary with the amount of moisture present in them from hour to hour and are also strongly influenced by the amount of electrolytic material (salts, etc.) which the textiles contain. Electrolytic material may be washed out producing a commercially realizable increase in insulation resistance of the order of 50 times the original value.*

The resistance of the animal fibers, silk and wool, is far greater for a given moisture content than that of cotton or of cellulose acetate, a derivative of cotton. It appears probable that the distribution of water as well as the quantity is important and that the two classes of fibers are characterized by different space patterns according to which the water is distributed. It is suggested that the space distribution patterns are associated with the colloidal structures of the materials and in turn with their chemical classification as proteins and celluloses respectively. Cellulose acetate absorbs little water as compared with cotton and is correspondingly superior electrically. However its resistance varies with moisture content in the sam way as that of cotton.

In spite of the great diversity of materials used for insulating purposes it is to a great extent absorbed water which determines their quality as insulators. Not only the amount of moisture but also its distribution is important, as is evident from the great variation in effect of a given increment of absorbed water upon the resistance of different materials such as cotton, silk, gutta percha, etc. Contamination of a variety of insulating materials with electrolytic impurities has also often been found responsible for poor insulating qualities. The textiles are peculiarly subject to the influence both of water and electrolytes.

Important contributions to the knowledge of the quantitative relations between the electrical properties of insulating materials and the moisture which they take up from the air have been made by Evershed,[4] Curtis,[5] Kujirai and Akahari,[6] Setoh and collaborators,[7] and other investigators. This paper is based upon an extended investigation of insulating materials particularly submarine insulation[2] and textiles[3] and is intended to emphasize the importance of moisture and electrolytic material on the behavior of textiles as insulators and to discuss briefly the relation of electrical characteristics to physical structure and chemical constitution, so far as possible with the available facts.

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1. Both of the Bell Telephone Laboratories, Inc., New York, N. Y.

2. Williams, R. R. and Kemp, A. R., *Jour. Frank. Inst.*, 35 (1927). Lowry, H. H. and Kohman, G. T., *Jour. Phys. Chem.* **31**, 23 (1927).

3. a. Murphy, E. J. and Walker, A. C., "Electrical Conduction in Textiles. I. Dependence of the Resistivity of Cotton, Silk, and Wool upon Relative Humidity and Moisture Content," *Jour. Phys. Chem.* **32**, 1761, (1928).

b. Murphy, E. J., "Electrical Conduction in Textiles. II. Alternating Current Conduction in Cotton and Silk," *Jour. Phys. Chem.* **33**, 200 (1929).

c. Murphy, E. J., "Electrical Conduction in Textiles. III. Anomalous Properties of Conduction in Textiles," *Jour. Phys. Chem.* **33**, (1929).

4. Evershed, *Inst. of Elec. Eng. Jl.* (London) **52**, pp. 51-83, 1914.

5. Curtis, Bur. of Standards, *Sci. Paper No.* **234** (1915).

6. Kujirai and Akahari, *Sci. Papers, Inst. Phys. & Chem. Res.* (Tokyo), **1**, pp. 94-124, 1923.

7. Setoh and Toriyama, *Sci. Papers, Inst. Phys. & Chem. Res.* (Tokyo) **3**, pp. 285-323, 1926.

Presented at the Winter Convention of the A. I. E. E., Jan. 28-Feb. 1, 1929. Complete copies upon request.

General Characteristics of Textiles

It is obvious that the rapidity of response of textiles to atmospheric moisture is due first of all to their fibrousness which permits ready access to the interior of the mass through the large surfaces exposed.

Single fibers of cotton and silk have a resistance[8] which, considering the nature of the material, is surprisingly uniform for different fibers taken from the same material. Threads[9] of cotton and silk also have a uniform resistance. Even where the voltage is applied transversely to the long axis of the fibers, the resistance of different samples of the same material is fairly uniform. These facts suggest that interfiber contact resistances are only secondary or negligible in determining the resistance of a thread or other mass of fibers.

The form of the sample is not of predominating importance with reference to the insulation resistance of either cotton or silk, and a marked contrast exists except at very high humidity, between cotton and silk, in all forms of samples. Both these facts and other available data justify the inference that the dielectric properties of textiles are determined primarily by the composition or internal structure of the fibers, not by the twist of threads or the lay of servings.

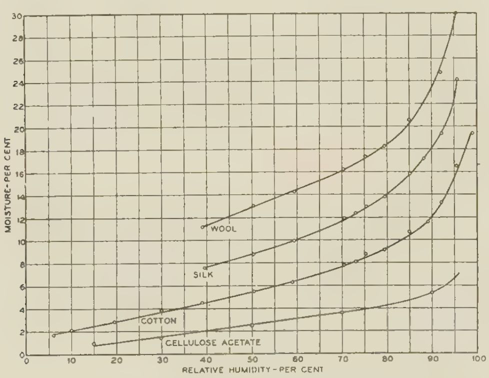

Fig. 1—Dependence of Moisture Content of Textiles upon Relative Humidity of Atmosphere with which they are Equilibrated

The moisture content of each sort of textile depends directly on the humidity of the atmosphere. Fig. 1 shows the moisture content of silk, wool, cotton, and cellulose acetate in equilibrium with air over considerable ranges of relative humidity. The data for silk and wool were taken from a paper by Schloessing;[10] those for cotton are due to Urquhart and Williams;[11] while those for cellulose acetate represent the figures of Wilson and Fuwa.[12] It is sufficient for our present purpose to emphasize the orderly dependence of moisture content upon the relative humidity of the atmosphere without discussing secondary phenomena or the full significance of the curves.

The relation of electrical behavior of each textile to relative humidity is also very close. Fig. 2 shows the insulation resistance of each of the above fibers plotted against relative humidity over the upper part of the range of atmospheric humidities. It is not practicable to plot the resistance over the entire range of humidity directly in this way, on account of the wide range of insulation resistance values which are obtained. In

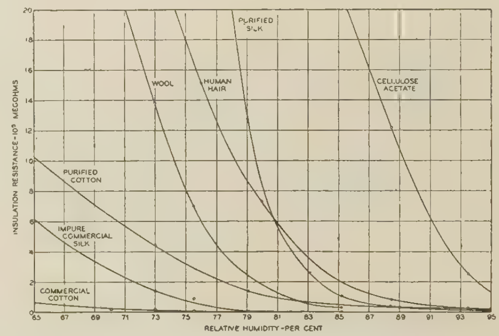

Fig. 2—Insulation Resistance of ½-In. Lengths of Textile Threads as Affected by Relative Humidity of Atmosphere

The purified cotton and purified silk had been submitted to a washing procedure to remove electrolytes. The impure silk was a commercial specimen representing somewhat more than usual contamination with electrolytes, while the commercial cotton is representative of its class

order to depict the fact that there is a consistent relationship throughout the range, we have plotted in Fig. 3 Log Insulation Resistance *vs.* Relative Humidity as far as values are at present available. When considered together, these three charts show that the insulation resistance of a textile depends on its moisture content, which in turn is a function of relative humidity. In other papers,[3] the electrical behavior of textiles in relation to relative humidity and moisture content is discussed more fully.

Perhaps the most significant evidence of the importance of electrolytic impurities in silk, wool, cotton, and to some extent other textiles, is the fact that their electrical characteristics can be greatly improved by thorough washing with water though without altering qualitatively the general nature of the electro-conducting phenomena which characterize them. Fig. 2 illustrates the result of washing upon the insulation resistance of cotton and silk threads. The improvement in insulation resistance of cotton and silk upon washing ranges commonly from fifty to one hundred fold, under any of the commonly prevailing conditions of atmospheric temperature and humidity. This im-

8. The experimental procedure is described elsewhere.[3a]

9. Because of their uniformity, small samples of thread (½ in. lengths) have been used in this laboratory as a convenient means of comparing the insulating quality of cottons and other textiles.

10. Schloessing, Th., *Bul. Soc. Encour, Indust. Nat.* **8**, 717 (1893); C. R. **116**, 808, 1893. Text. World Record, Boston, Nov., 1908, p. 219.

11. Urquhart and Williams, *J. Textile Inst.* **15**, 143, (1924).

12. Wilson, R. E. and Fuwa, Tyler, *Ind. & Eng. Chem.* **14**, 913 (1922).

provement is accompanied by diminution of the ash content, in the case of cotton from about 1.0 per cent to 0.15 or 0.25 per cent. It produces only a slight reduction in the equilibrium moisture content of the cotton over the ordinary ranges of atmospheric humidity. Commercial silks are similarly affected by washing.

If the mineral contents of cottons which have undergone washing are compared quantitatively with the original contents a decrease is observable, particularly as to potash, but the calcium and magnesium contents are much less altered. Fairly complete removal of potash is apparently essential to good electrical characteristics, but improvement electrically has been attended in some cases by an actual increase in content of alkaline earths. This suggests that interchange of electrolytic impurities between the textile and the water is involved as well as actual removal of electrolytes by the water. Thus in general hard natural waters, *i. e.*, those containing calcium and magnesium salts, have proved as good or better than soft waters when used in economically small amounts. Very exhaustive extraction with distilled water gives excellent results, though not vastly superior to washing with very dilute solutions of alkaline earth salts. Sufficiently complete and accurate analyses of samples of textiles brought into equilibrium with washing liquids and of the kind and quantity of electrolytes in the corresponding liquids have yet to be made to determine the precise importance of the composition of the saline residues. Non-saline electrolytes have also to be considered. This matter requires extended study and the experimental data are reserved for future publication.

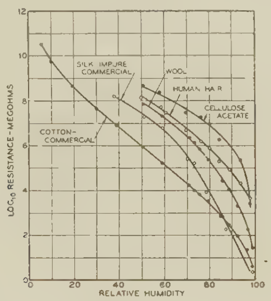

FIG. 3—LOG INSULATION RESISTANCE OF ½-IN. LENGTHS OF TEXTILE THREADS *vs.* RELATIVE HUMIDITY OF THE ATMOSPHERE

For description of samples see Fig. 2. For tabulated data see reference 3a

The commercial value of such treatments of insulating yarns have proved to be very substantial. The utilization of the products forms the subject matter of another paper from the Bell Laboratories.[13]

DISTINCTIVE CHARACTERISTICS OF EACH FIBER SPECIES

The several kinds of fibers exhibit a number of curious contrasts in the relation of electrical behavior to hygroscopic properties, some of which at first glance appear contradictory. For convenience in discussion let us classify the commercial fibers into two main groups: (1) the animal fibers, and (2) the vegetable fibers, and a sub-group (2a), the cellulose ester fibers of which the so-called cellulose acetate silk is the sole representative of commercial importance at present. It will be seen by reference to Fig. 1 that over the entire range of relative humidity the animal fibers, silk and wool, absorb more water than the natural vegetable fibers. This is true whether we deal with fibers in their natural impure state or after a washing process which has been shown to improve greatly the electrical characteristics of both types of natural fibers. Cellulose acetate absorbs less water at any given humidity than either class of natural materials.

We have seen that for any given kind of fiber there is an orderly dependence of electrical properties upon the moisture content of the fiber and in turn upon the relative humidity of the atmosphere. The more water present in any given fiber the poorer are the electrical properties. If the amount of water in fibers were the sole determinant of electrical characteristics we would expect the animal fibers to be, at a given humidity, the poorer electrically of the classes enumerated above.

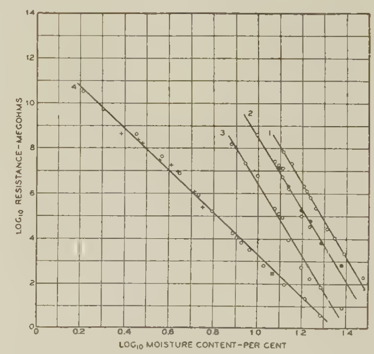

FIG. 4—INSULATION RESISTANCE AS A FUNCTION OF MOISTURE CONTENT OF TEXTILES

1. Wool yarn
2. Silk threads purified (○ sample 1 ● sample 2)
3. Silk threads impure
4. ○ Cotton threads, + cellulose acetate threads

But this is emphatically not the case. With respect to electrical properties, we find that the vegetable fibers are inferior to the more hygroscopic animal fibers and are also inferior to the least hygroscopic variety of commercial fiber, *viz.*, cellulose acetate. To make the existing contrast clear we have plotted in Fig. 4 for the several textiles, Log Insulation Resistance *vs.* Log Moisture Content. When so plotted the values for each kind of fiber fall approximately on straight lines throughout the range of actual measurement. The relative position of the curves for animal fibers to the right and above that for cotton[14] means that the animal

13. Glenn and Wood, *This Journal* 48, 146, 1929.

14. The threads referred to are approximately, but not precisely, of the same size. This variable is by no means sufficient to account for the higher position of the animal fibers as compared with cotton.

fibers have the better insulating qualities in spite of higher hygroscopicity.

The slopes of these lines have an even greater significance for they indicate the relative sensitivity of the fibers to an increment of moisture. Since the slope for the animal fibers is greater, it is evident that the animal fibers are more sensitive electrically to moisture than cotton. Under a given set of conditions they are not only wetter than cotton, but are more sensitive to the effects of further increments of moisture and yet they have a higher insulation resistance.

In one respect alone can we say that cotton is preferable as an insulating material. It has the merit of being more nearly uniform in behavior under a variety of weather conditions. When the amount of moisture taken up from the surrounding atmosphere by silk or wool is doubled, the electrical leakage increases by a factor of 50,000 to 100,000, while that for cotton rises by a factor of only 600.

The position and slope of the values for cellulose acetate are of great interest as the curve coincides with that for cotton, indicating that moisture affects these two fibers in a very similar manner. The essential electrical difference between these two appears to be satisfactorily accounted for by the fact that cellulose acetate absorbs less water than cotton at any given relative humidity of the atmosphere. The conversion of cotton which is essentially cellulose into cellulose acetate by the process of acetylation, has, as could be predicted on chemical grounds, reduced its hygroscopicity but apparently has not modified its structure greatly. Cellulose acetate is therefore put in a subgroup rather than in an independent classification.

We are justified on chemical grounds in classifying the fibers in the same way which we have found to be convenient for discussion of their hygroscopic and electrical properties. How much importance should be attached to this correspondence between the chemical and electrical classifications cannot be determined at present. However, the correspondence seems suggestive and deserving of a brief discussion. The first class, that of animal fibers, has a common chemical nature in that they consist largely of proteins.

That their common protein character is responsible in some way for the properties of principal interest from the insulating standpoint is rendered the more probable by the close resemblance of silk and wool, as shown by the approximate parallelism of their curves in Fig. 4. This resemblance is shared in considerable measure by other hairs than wool.

The second class of fibers, coming from the vegetable world, are alike in being composed of cellulose, a substance like the protein in having a high molecular weight but unlike it in that its polar groups are hydroxyls which have a faintly acidic rather than amphoteric nature. These are the groups in cellulose with which water is likely to associate itself. Such data as are available concerning vegetable fibers other than cotton, notably linen, ramie, manila hemp, and wood pulp, indicate a strong resemblance not only chemically but hygroscopically and electrically.

The sub-class embracing only cellulose acetate as a commercial fiber is chemically more neutral and non-polar in type than other cellulose fibers, with which fact it is reasonable to associate its lower hygroscopicity and consequent better electrical characteristics. It is probable that cellulose nitrate and cellulose ethers will be found to fall in this class but artificial silks other than cellulose acetate absorb more water and appear on chemical grounds to be better classified with the cellulose fibers of natural vegetable origin.

The fact that the electrical characteristics of the two classes of fibers as affected by moisture appear to be specific properties of the substances involved suggests some highly regular distribution pattern of conducting water paths determined by the chemical or physical (colloidal) structure of the material. Such a regular pattern may involve only water condensed upon the surfaces of the elements of structure in such a way that the thickness of the film varies regularly from point to point through the material. Accumulation of water at thick points would have little electrical effect, while that in thin portions would be very significant. An alternative regular mode of distribution would involve water in part dispersed in solution or chemical combination within the units of structure of the material and in part in fairly uniform thin films on their surfaces, in which case the latter would have the major electrical consequence. While such a regular form of distribution seems preferable, it is perhaps not the only way of accounting for the electrical properties observed.

ARCING LINE CONNECTORS CAUSED INTERFERENCE

A baffling case of radio interference caused much distress to the citizens of Albert Lea, Minn., some time ago. The interference manifested itself as a continuous sound, obviously caused by a maintained arc. It was finally located by means of a portable set inside of a sleeve clamp connecting an aluminum to a copper conductor on a transmission line on the outskirts of the city. The hole in the connector for the reception of the aluminum conductor was lined with aluminum and the hole for the copper conductor was lined with copper. The man who installed the connector reversed it so that the contacts were between unlike, instead of like, metals. Corrosion occurred in the course of time, until finally an arcing contact was established. When the connector was replaced the interference ceased, thus terminating a prolific source of radio complaints.—*Electrical World.*

Abridgment of

Southeastern Power & Light System

Interesting Features of Development and Operation

BY A. T. HUTCHINS*

Non-member

Synopsis.—The rapid growth of the Southeastern Power & Light system is noted. Long forecasts, operating methods and new plant designs are discussed briefly.

AMONG the larger groups of public utilities, the Southeastern Power & Light Company is scarcely more than an infant. Organized in 1924, the last important changes in its structure were made only a few months past. The generation reported for 1925, 1926, and 1927 were approximately 1.2, 2.0, and 2.2 billion kw-hr. The increase in 1926 over 1925 was largely due to the addition of the Georgia companies.

ADVANTAGES FROM INTERCONNECTION

During its short life there have been realized for its subsidiaries many important benefits from physical interconnection and coordinated load dispatching. Improvement in economy of operation has been secured, first, by carrying the load of small communities over lines from sources of low cost of generation, and second, by coordinated use of hydro plants of the storage and run-of-river type and of steam plants, and by construction of new plants in units of large capacity. Improved service has been secured through better interconnections and increased number of sources of power. The advantage to the load districts resulting from service from a number of lines from different directions is easily appreciated when it is noted that severe meteorological disturbances do not often occur simultaneously over a wide area. Usually only a narrow zone is affected by wind storms of such severity as to disable a circuit so that it cannot be reclosed after tripping. Similarly storms accompanied by severe lightning usually travel over the country so that these disturbances are not simultaneous over wide areas. In general, the larger loads are supplied by lines and plants of such capacity that service is maintained even if more than one line is out of service. These facts explain the great improvement secured by building lines supplying the same area along routes separated from each other.

SYSTEM PLANNING

Extensive surveys of load prospects in every section of the territory have been projected several years into the future. Although it is known that the best of such estimates will miss the final development the location of important water power sites is known, the extent of coal fields and coal qualities are fairly well known, and the major trunk lines for the system have already been built. With this foundation, a study of load densities for the various sections of the system, extending ten or twelve years into the future, is of value principally to prevent any construction which would not fit with good economy into the final set-up. This being secured, the procedure resolves itself into making definite plans to care for load conditions two years in advance.

In general, the hydraulic structures being built for this system have a relatively high factor of safety, due to the point of view of the engineers, and, no doubt, partly to the comparatively short history of stream flows resulting in a greater uncertainty as to maximum flow to be expected.

The design of Jordan Dam which is located about 18 mi. down stream from Mitchell Dam on the Coosa River makes use of a variation in forebay level and the buttress type of power house which may be of interest.

Descriptions of the Thurlow back-water suppressor installed at Mitchell Dam have been published.* It is only necessary to note that the use of the suppressor will maintain normal head on the plant with flows up to 170,000 cu. ft. per sec. at which flow the tail race is up about 15 ft.

The design at Jordan Dam takes advantage of this feature and raises the forebay level 7 ft. to compensate for tail-race rises at high flows.

The normal tail-race level at Mitchell Dam is at elevation 282 to 283. The spillway at Jordan is 1122 ft. long with 612 ft. open at elevation 283. The remainder is controlled by 17 gates whose crest is at elevation 290, each gate being 30 ft. long and 18 ft. deep.

With a stream flow of 52,000 cu. ft. per sec. approximately 17,000 cu. ft. per sec. may be used through the four 36,000-hp. wheels and 35,000 cu. ft. per sec. will flow through the open spillway section bringing the forebay level to the elevation 290 and actually increasing the head on the plant. It is expected that this seven-foot rise in the forebay level will compensate for

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Presented at the Regional Meeting of the Southern District No. 4 of the A. I. E. E., Atlanta, Ga., Oct. 29-31, 1928. Complete copies upon request.

*"New Developments in Hydroelectric Power Plant Designs," by J. A. Sirnit, Amer. Soc. Mech. Eng. *Trans.*, Vol. 44, p. 361-'22.

the tail race rise up to stream flows of 75,000 cu. ft. per sec.

It is apparent that while 283 is the elevation for the tail race at Mitchell Dam and also the open spillway at Jordan, the backwater suppressor at Mitchell Dam will maintain full head against the rise of seven feet.

In addition to this, the open spillway avoids the necessity for operating spillway gates except for flows above 52,000 cu. ft. per sec.

A general idea of the buttress type power house is shown in Fig. 4. At each end of the building and between units, buttresses extend from the upstream face of the powerhouse to the solid masonry between draft tubes, thus carrying the greater part of the load on this section of the dam. Such design permits the location of units 40 ft. nearer the face of the dam, and shortens the penstocks by that distance.

Steam Plants

The use of either 600-lb. or 1200-lb. pressure of steam with reheat cycles and the combined cycle of mercury vapor and steam has had wide publicity and plants using these cycles are increasing in number with a possible trend to neglect 600-lb. pressure and step from 400-lb. to 800-lb. or 1200-lb. pressure.

The most recent unit under construction on this system is designed to use 400-lb. pressure at the turbine throttle, a steam temperature of 725 deg. fahr., and a net economy of the plant for a year's output of approximately 16,000 B. t. u. per kw-hr. On account of high temperatures of circulating water at Gorgas, this unit was designed for best efficiency with 2-in. back pressure at the exhaust nozzle. Some of the essential features of this unit are as follows:

Turbo generator—60,000-kw., 90 per cent power factor, 13,800-volt, single-shaft, 1800-rev. per min., closed generator cooling system using raw water for cooling.

Turbine—three valves 17-stage with 4 bleed points for heating the feed water to 360 deg. fahr. at 52,000 kw. load and a B. t. u. rate chargeable to the turbine—11,350 B. t. u. per kw-hr. at that load.

The unit is built for a maximum load of 66,667 kw. at unity power factor. Steam will be supplied to this turbine from two boilers, each rated at 3040 hp. and equipped with pulverized fuel burners and fans of sufficient capacity to secure a maximum rating of 450,000 lb. per hr.

It was found that the increased capacity of the turbine and slight increase in efficiency more than compensated for the added cost of valves and fittings designed for 600-lb. pressure over those for 400-lb. pressure.

The use of air preheaters and a correspondingly high temperature of gases leaving the boiler surface with the high pressure used showed good economy in the use of the fourth bleed point for feed water heating. However, on account of crowding of piping and heaters and consequent difficulty in operation and maintenance, it is likely that the next unit will use only three bleed points for feed-water heating.

Lines and Tie-in Facilities

Lines are always designed for economy based on load and use factor but the necessity for carrying loads with one or more circuits out results in a system which is more or less flexible and which, under certain conditions, makes a maximum use of regulating equipment such as synchronous condensers or spare generators operated as condensers.

At this time 125,000-kv-a. capacity in synchronous condensers is installed at advantageous points on the system. One of these having a capacity of 15,000 kv-a., located at Lindale, Georgia, is equipped with a high-speed excitation system. A 90-mi. line from the U. S. Government plants on the Tennessee River to Gorgas, near Birmingham, has been in operation at 154 kv. for some time. A 133-mi. line from Martin Dam to the Atlanta district is spaced and insulated for the same voltage. Three of the newer hydro plants, the last of which will not be in service until next year, were designed for high-speed excitation.

In a system so extensive and having generating plants using stream flow varying so greatly from season to season or over a cycle of years the securing of high load factors on transmission lines is extremely difficult and increased losses, due to overloading under unusual conditions, must be accepted in place of the cost of additional copper and a lower use factor.

The combination of run-of-river and storage plants, served by the same lines, is, in general, advantageous, but extreme conditions arise under which it is not practicable to transmit with normal losses the output from these plants to the load.

Reports from individual plants show the details of operations. Steam-plant reports include a heat balance for the day's operation, and hydro plant reports show a record of water used, stored, or passed over the spillway. At the hydro plants records of the operation of the wheels at the gate opening used and the discharge through the spillway gates are employed to check the stream-flow gages. For some time there has been in progress a series of tests which will include one unit of each of the various sizes and manufacture. To date these tests have been of high value.

It is often possible to install at the time of testing a pair of piezometers in the penstock and scroll case so arranged that the differential may be determined by the use of a manometer and the values plotted in terms of water flow and thus be available for check runs at any later date.

It is found that a careful audit of stream flow and water use, especially for flows less than the capacity of the plant, is of real value in securing maximum output or maximum time operation at gate openings of high efficiency. This, of course, implies a nice cooperation between plant operators and load dispatchers.

Load Dispatching

The load dispatchers must be responsible for coordinating the entire system, not only for daily and weekly runs but they must follow through for an entire year or even a cycle of two or three years.

In general, the run-of-river hydro plants are operated on the base load whenever the stream flow approaches the capacity of the plant. During the dry weather such plants are operated on a daily or weekly cycle to secure the maximum output in hours of peak load. On the other hand, those hydro plants supplied from storage reservoirs will be operated on a schedule based on stream-flow variations for a year or even more, and effort is being made to have full reservoirs available for the dry season of each year, including a year of low stream flow. This will permit replacing some of the loss of capacity at the run-of-river hydro plants resulting from extremely low stream flow.

The steam generation will vary widely from a minimum during wet weather seasons, when run-of-river plants are carrying full load, to a maximum during periods of lowest stream flow.

Typical plant operation during a wet and a dry day in a year having ordinary seasonal stream flows is shown on Figs. 2 and 3.

Fig. 2 shows conditions in October of 1927 when the storage plants existing at that time were being used for a considerable output to supplement the run-of-river plants at which the stream flows were low during that month. The steam plants operated throughout the twenty-four hours of the day together with run-of-river energy purchased from the government at Muscle Shoals, which plant was available only on a basis of constant output. The other run-of-river power was blocked into the daily peak together with most of the output from the storage plants.

In a sharp contrast to this, Fig. 3 shows the daily load diagram for March of 1928 under conditions which may be termed normal in wet weather. Storage at this time was being built up, and the most efficient steam plants were being run for a half million kw-hr. daily, as shown, to carry the load with the output from the run-of-river hydro plants and a small output from the storage plants. Stream flow into storage above that used by the plants is plotted above the load curve.

The output from the storage hydro plants of the system in service in 1927, secured by a maximum drawdown was approximately 230,000,000 kw-hr.

The use of Upper and Lower Tallassee plants, the first finished in June 1928 and the latter to be put into service in 1929, will increase this output through the use of water stored at Martin Dam by approximately 130,000,000 kw-hr. so that the output from stored water in 1930 will heave nearly the same ratio to the total load at that time as shown in these load diagrams.

The maximum hourly load carried by the storage plants in 1927 is shown as 165,000 kw. with fairly long-hour use. Capacity available in 1930 will be double this amount with provision in the hydraulic structures for 80,000 kw. additional which may be installed when the proportion of steam generating capacity has greatly increased and the storage plants are pushed higher into the peak. The economy of such added capacity at

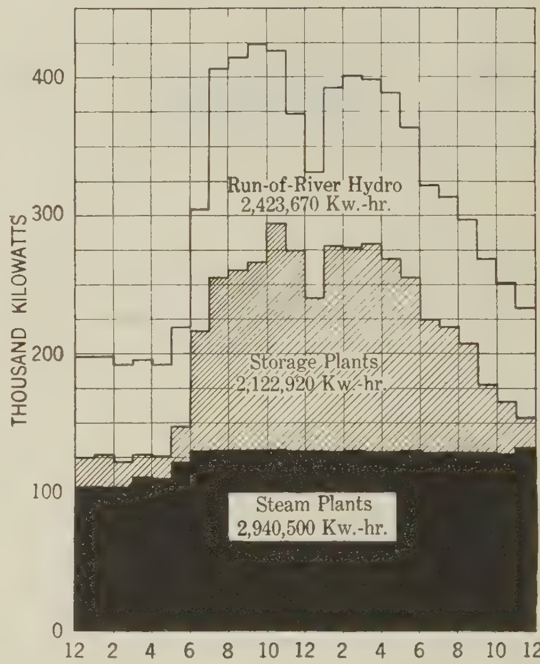

Fig. 2—Load Curve—Typical Day, Normal Dry Month

the hydro plants is based on a cost of construction of about 50 per cent of that for steam units.

This cost does not include the lines and tie-in facilities and therefore some advantage would be lost if the peak loads to be carried were served over new circuits at a greater distance in the case of hydro units than for steam units.

Seasonal Maintenance of Equipment

On a system where the only source of supply is from steam plants, there is necessarily provided sufficient capacity so that units may be available in turn as required for inspection. Practically all operating companies make it a practise to inspect the large turbines once every year. On such systems, it sometimes happens that the load demand approaches capacity so closely that the inspection must be made during

seasons of low demand, thus making all equipment available for operation during the year's peak.

In contrast with this, it is interesting to note the schedule of inspection and maintenance possible where the plants have a fairly definite seasonal requirement. On this system turbo-generator units at the steam plants are scheduled for inspection during the wet month of the year, which are included in January to June. During this time, besides the regular dismantling and inspection, any pre-scheduled major repairs are also undertaken. Similarly the work on the hydraulic units at the run of river plants is undertaken during the dry months when only a portion of the installed equipment is needed to use the entire stream flow.

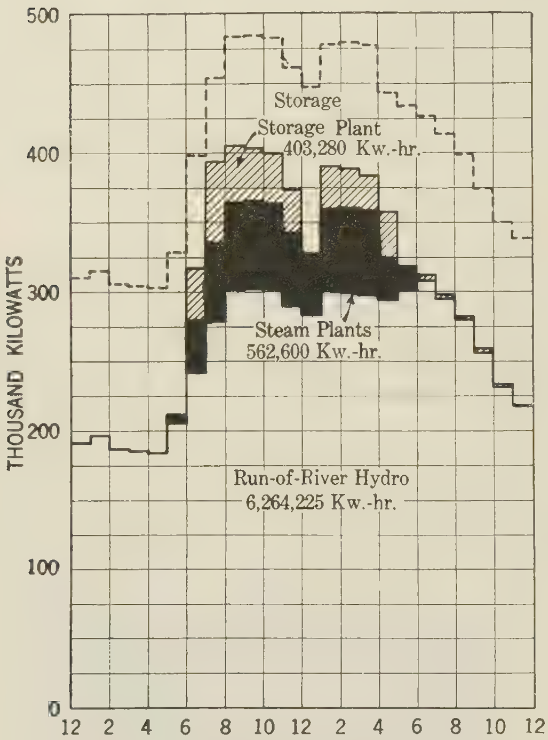

Fig. 3—Load Curve—Typical Day, Normal Wet Month

Repair of Wheels by Electric Welding

Very rapid pitting of cast iron runners at one of our plants brought about conditions calling for extensive repairs by welding. Cast steel inserts of considerable size were used and the metal of the wheel surrounding these was built up to normal thickness by electric welding.

The results of this work have emphasized to our operators that repairs should not be delayed in the hope that the pitting will cease as a natural course of events.

Besides such maintenance work, we find it necessary to overhaul completely the moving parts from the servo-motors to and including the wicket gates every twelve to fifteen years. This work includes the replacing of worn liners, bushings, rings, pins, welding up the shafts of wicket gates which may be worn, and, in general, bringing these parts of the machine practically to a new condition.

By carrying on maintenance as far as practicable during the season of low generation at the steam plants a further benefit is secured, namely, the reduction in labor turn-over and a more advantageous use of the force of men necessarily continuously employed at the steam plants.

Modern steam-electric units should be available for use 85 per cent of the time. With spare units available to permit inspection and repair, the factor of availability, when required, should approach 100 per cent. By means of scheduling inspection as outlined above, we have obtained a factor of availability, when required, of 99 per cent for three years, and of 99½ per cent for the year 1927.

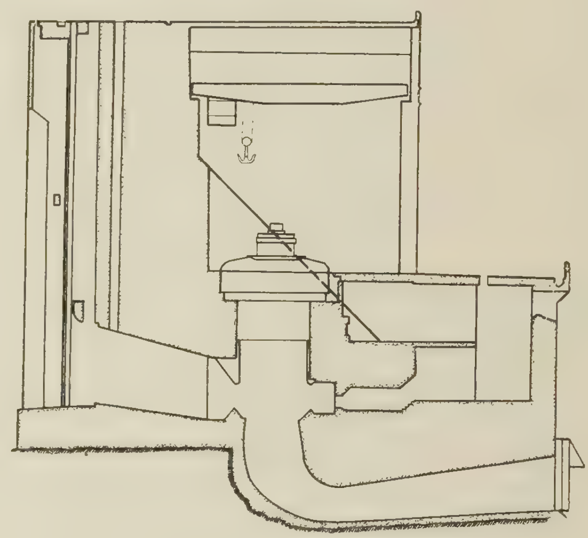

Fig. 4—Jordan Dam Power House

Transverse cross-section through center line of unit

Hydraulic Structures

Throughout the history of the subsidiary companies of the Southeastern Power & Light Company there has never been any necessity for repairs to hydraulic structures at any of the major plants.

In the foregoing paragraphs we have touched very briefly upon those features of system extension, operation, and maintenance which seem to us to present points of at least passing interest.

Abridgment of

Automatic Reclosing High-Speed Circuit Breaker

Feeder Equipment For D-C. Railway Service

A. E. ANDERSON*

Associate, A. I. E. E.

Synopsis.—*High-speed circuit breakers have been used in both feeder and machine circuits of railway substations. It is the purpose of this paper to point out some of the advantages gained by placing this type of breaker in the feeder circuit and also to describe some of the more common types of feeder equipment using a well-known form of high-speed circuit breaker. A brief summary of the breaker characteristics is given, together with the results of short-circuit tests made on 600-volt reclosing feeders employing this type of breaker.*

The reclosing action is ordinarily obtained by means of a relay which, in conjunction with a load indicating resistor, measures the resistance of the external circuit. In order to permit feeder conditions to reach a stable value and particularly to enable all transient and counter e. m. f. effects to disappear before the reclosing devices are given control after the opening of the breaker, the action of this relay is purposely delayed. The latter effects usually disappear within a few seconds of the opening of the breaker on the usual type of railway circuits. In a majority of cases a time delay of 10 to 30 seconds (after the opening of the breaker) elapses before the reclosing devices are given the control of the breaker. After this time delay has expired and load conditions have reached the desired value, the circuit breaker is reclosed.

In some cases, especially for sectionalizing purposes, it has been found satisfactory to take the reclosing indication and control from the load side of the breaker. This feature requires that some other breaker undertake the reestablishment of voltage on the load circuit. By means of supervisory control the range of such equipment can be extended so as to pick up a dead section during abnormal operating conditions.

A majority of 3000-volt installations has been made in connection with main line electrification where the desired reclosing operation is a combination of load-indicating and load-limiting functions. Voltage increments on the load of too large a value may increase the tractive effort to such values as to cause wheel slippage of the locomotive, or snapping of draw-bars; consequently the load voltage is raised in graduated steps by progressively short-circuiting portions of load-limiting resistors placed in the feeder circuit.

* * * * *

Characteristics of the High-Speed Air Circuit Breaker

THE type of automatic reclosing equipment described in this paper makes use of a well-known magnetically-held high-speed air circuit breaker. A brief explanation of this type of circuit breaker, as illustrated in Fig. 1, may aid.

The breaker is a self-contained device. It is closed by means of a closing or reset coil which seats an armature against the pole faces of the holding magnet. During this operation, the auxiliary contacts move between the positions corresponding to the open and closed positions of the breaker, but the main contacts do not close until the closing or resetting mechanism is returning to the open position. Due to this function, which is obtained by a suitable system of levers, etc., the breaker is free to trip during the closing operation.

A set of springs is attached to the moving contact. These springs exert a certain amount of opening force when the breaker is held in the closed position.

The breaker may be opened in two ways; (a) by decreasing the holding coil current, or shunting flux from the holding armature; (b) by decreasing the holding coil current, a point is reached where the opening springs overpower the holding effect and the contacts consequently open. The breaker is tripped on overcurrent by means of a trip coil or bucking bar which is so placed in relation to the magnetic circuit as to shunt or transfer enough flux from the armature, thereby decreasing the holding effect and allowing the contacts to be opened by the opening springs.

The holding coil is connected in shunt with the source, which fixes the polarity of the holding flux. In order to shunt the flux set up in the armature by the holding coil, the current in the tripping circuit must flow in a certain direction. If it flows in an opposite direction it merely tends to increase the flux in the armature as already set up by the holding magnet. Due to this relation of the magnetic circuits, the tripping characteristic of the breaker may be said to be polarized, and in order to trip the breaker current, must flow in a given direction in the line.

Advantages of Placing the High-Speed Circuit Breaker in the Feeder

Fig. 2 shows a typical installation of high-speed circuit breakers as part of reclosing feeder equipments in an automatic substation. By placing these breakers in the feeder circuit it is possible to remove any suddenly applied overloads or faults without any serious effect on the remaining feeders supplied from the station. The feeder handles its own circuit conditions without reflecting them back to the machine, which might cause the insertion of steps of machine load limiting resistors, reduce the voltage on the remaining feeders, and consequently decrease the car speed.

If conditions warrant the use of a high-speed circuit breaker in the machine circuit, together with corresponding breakers in the feeder circuits, it is possible to

1. Switchboard Engg. Dept., General Electric Co., Philadelphia, Pa.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

select the trip points and the discriminate so as to permit the feeder breaker to trip first.

There are conditions when the machines in an automatic substation are shut down; for example during light-load periods; but the feeder breakers are closed so that the station bus becomes a tie point between the feeders, some of which may be feeding power into the bus and the balance feeding outwardly. All feeder breakers in this case are connected so as to trip only on outgoing current. This inherent polarized tripping characteristic of the breaker has been described above.

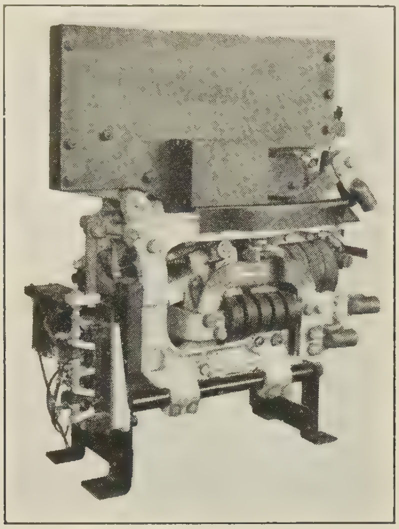

Fig. 1—600-Volt D-c. 2000-Ampere Magnetically-Held High-Speed Air Circuit Breaker

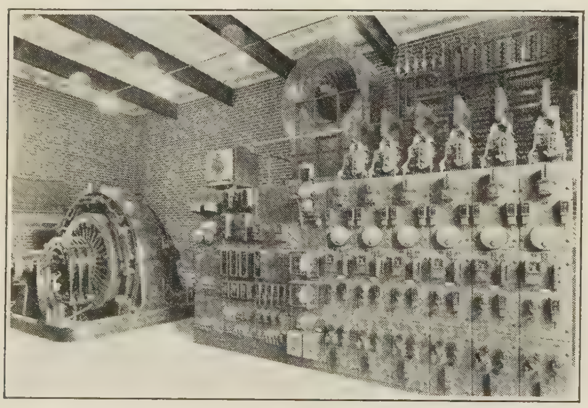

Fig. 2—Automatic Reclosing High-Speed Circuit Breaker Feeder Equipments as Installed in a 600-Volt Automatic Railway Substation

When a fault occurs on one of the feeders, only that particular feeder is tripped, since the remaining feeders are either carrying current below their trip points or else the current is flowing through their trip circuits in a reversed direction.

Other operating conditions may sometimes find two or more breakers in series (at different substations) with the fault current flowing through them in a direction to produce tripping. Due to the decreased voltage across the holding coil of the breaker nearest the fault, it will be found that its trip point is reduced below that of the breaker nearer the source. This results in tripping the breaker nearest the fault and isolates only that section of the system on which the fault occurs.

As contrasted with slower forms of circuit interrupters, the use of a high-speed circuit breaker results in a material reduction of the peak current of the faulty feeder. A comparison of the interrupting characteristics of common forms of air circuit breakers is given more fully in the comments pertaining to Fig. 5.

The trip-free characteristic of the high-speed breaker permits it to be closed on heavy overloads or faults where the reclosing relays are in the open position. Contrary to the indication of the reclosing devices the breaker in such cases may be closed by means of supervisory or manual control.

Description of 600-Volt Feeder Equipment

High-speed air circuit breakers were first applied to d-c. reclosing service over five years ago. The construction of this type of equipment is illustrated in Fig. 2.

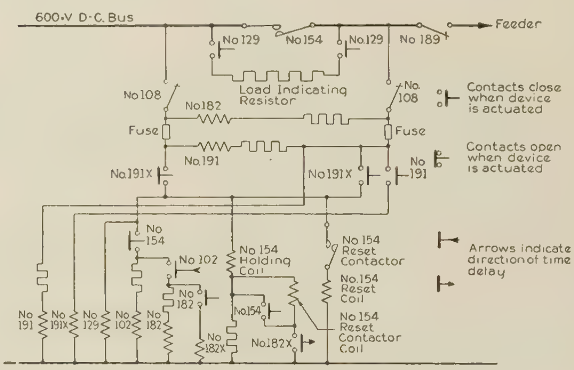

Fig. 3—Elementary Circuit Diagram of Automatic Reclosing Feeder

For 600-volt service using a continuous load indicating scheme and suitable for stub-multiple feed in either direction

A design of reclosing feeder using a continuous load indicating scheme is indicated in elementary form by Fig. 3. The reclosing relay No. 182 is of the so-called "balanced" type. The restraining (or opening) coil is connected across the load-indicating resistor. The actuating (or closing) coil is connected across the source of voltage. With a short circuit on the feeder, the restraining coil has full operating voltage impressed upon it. This action causes the contacts of No. 182 to open and remain open. Some time later, as determined by the setting of the time delay relay No. 102, the actuating coil is connected across the operating source. Both the actuating and restraining coils now have full operating voltage impressed across their respective

circuits. The relay (No. 182) is so adjusted that under this condition the restraining coil overpowers the actuating coil and the relay contacts remain open. As the load resistance increases, the voltage drop across the load indicating resistor decreases. This decrease also takes place across the restraining coil; consequently, a predetermined load value is reached where the actuating

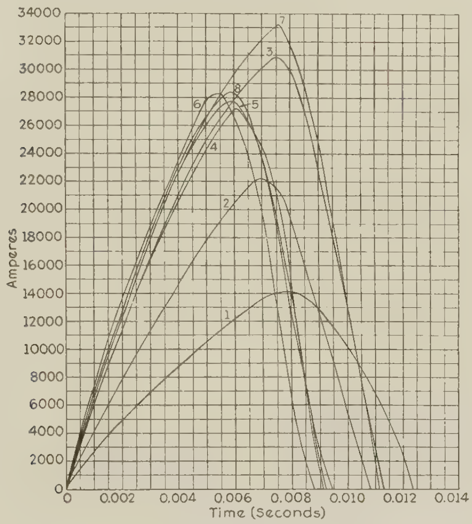

Fig. 4—High-Speed Air Circuit Breaker

Opening a short circuit at 600-volts with different combinations of machines supplying power. Resistance of external circuit 0.002 ohm

Curve No.	Kw. connected to station bus	Maximum rate of rise, amperes per second
1	2,000	3,050,000
2	4,000	4,250,000
3	6,000	6,650,000
4	7,000	6,050,000
5	8,000	7,400,000
6	10,000	7,600,000
7	11,000	7,000,000
8	12,000	7,000,000

coil overpowers the restraining coil and the relay contacts close. The latter operation energizes an auxiliary relay, No. 182-X, which in turn closes the circuit breaker, No. 154. The reclosing relay, No. 182, is so adjusted that it operates at a fixed voltage ratio over a wide range of operating voltage. By this characteristic, the feeder recloses on a fixed value of load resistance, regardless of the value of the source voltage. In case another station is supplying the load (multiple feed), when the same voltage ratio is obtained the feeder recloses.

Control power is obtained from either side by means of the voltage directional relay, No. 191, and its auxiliary, No. 191-X. An isolating contactor No. 129, is used to disconnect the load indicating resistor when the feeder is taken out of service, by opening the control power switch No. 108.

Results of Current Interrupting Tests on 600-Volt Reclosing Feeder

An extensive set of tests was made on a street railway property using the type of feeder as illustrated in Fig. 2. One feeder was installed in a station where the connected synchronous converter capacity (25 cycles) could be varied, in certain steps, from 2000 to 12,000 kw. One set of tests was made in which the short circuit was applied immediately outside the station, giving an external circuit resistance of 0.002 ohm. The results of these tests as given in Fig. 4 show that the peak current increased as the connected machine capacity increased from 2000 to 6000 kw. From 6000 to 12,000 kw. there was no corresponding increase; in fact most of the peak values were slightly under the peak value corresponding to the 6000 kw. condition. This same type of breaker has successfully interrupted currents as high as 61,500 amperes at 600 volts.

The comparative time-current tripping characteristics of the high-speed and other more common forms of circuit breakers may be obtained from Fig. 5. These tests were made at 600 volts, with the same external circuit conditions and with the same amount of con-

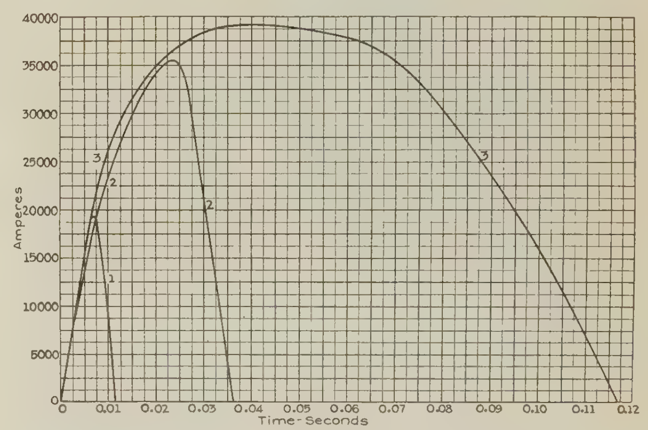

Fig. 5—Comparative Time-Current Tripping Characteristics

Of correspondingly rated magnetically-held high-speed circuit breaker (Curve 1), mechanically latched circuit breaker with fast moving parts and magnetic blowout on arcing contacts (Curve 2), and mechanically-latched circuit breaker with carbon arcing contacts (Curve 3). Tests were made with the same external circuit conditions and with the same amount of connected power

nected conversion apparatus. Curve 1 shows the time-current tripping characteristic of the high-speed circuit breaker as illustrated in Fig. 1. Curve 2 is the corresponding characteristic of a relatively fast panel-mounted mechanically-latched circuit breaker having a magnetic blowout associated with the arcing contacts. Curve 3 illustrates the corresponding characteristic of the usual panel-mounted air circuit breaker (mechanically-latched) having carbon arcing tips.

Description of 1500-Volt Feeder Equipment

High-speed circuit breakers have been applied to

1500-volt reclosing service. Such an equipment, as illustrated in Fig. 6, makes use of the continuous load indicating scheme as outlined in connection with Fig. 3.

Another application of this type of equipment has been made to cross-tie and sectionalizing points. Fig. 7 illustrates a typical system consisting of three generating stations, designated as Nos. 1, 2, and 3, feeding four track circuits. At convenient points along the system there are installed certain cross-tie and sectionalizing buses. This arrangement results in confining the fault to a particular section without a loss of service on other sections and, in addition, permits the feeder and trolley copper to be used to advantage during normal operating conditions.

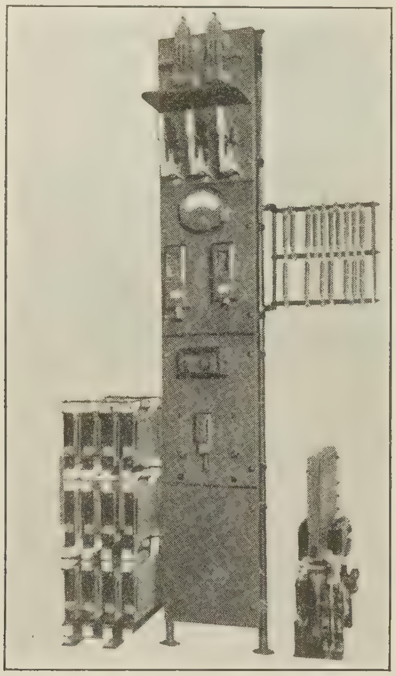

Fig. 6—1500-Volt, 2000-Ampere D-C. Reclosing Feeder

Using a high-speed circuit breaker and a continuous load-indicating scheme. Circuit breaker and load-indicating resistor shown respectively, to the right and left of the panel

If a short circuit should occur on Track No. 1 in the section fed from station No. 2, not only will the corresponding feeder breaker at station No. 2 be tripped, but also the two breakers which feed each end of the faulty section from the adjacent cross-tie and sectionalizing buses will be tripped. The selective operation of the breakers at these points is obtained by having them trip on outgoing current only, which is readily available due to the polarized tripping characteristics of the type of high-speed breaker covered by this paper. Another characteristic used advantageously in such an installation is the reduced holding coil voltage of the breaker nearest the fault. This characteristic, together with current flowing in the proper direction, gives the desired selectivity.

The breakers usually reclose when voltage has been reestablished for a definite time on the faulty section, either by the station breaker or by the sectionalizing breaker at the other end of the section. By means of supervisory control it is possible also to reclose the sectionalizing breaker from its corresponding bus.

The stub feeders at the end of the system obviously obtain their control from the bus at all times. Those feeding in multiple with other feeders can reclose from the bus (by means of supervisory control) or in response to voltage restoration, on the track circuit. The normal reclosing operation is on voltage restoration.

Description of 3000-Volt Feeder Equipment

The application of reclosing feeders to 3000-volt d-c. railway circuits includes a number of problems not encountered at the lower voltages. Principal among these is the fact that this voltage has been applied to main line electrification with long trains and also with longer distances between stations. Tests have been made in the field, showing that if, too large a voltage increment is placed on the locomotive, there is danger of suddenly increased tractive effort which will cause the wheels to slip or the draw-bars to snap.

The investigation of this problem has led to the development of a combined load-indicating and load-limiting feeder. The load-indicating resistor determines whether a short circuit exists on the feeder and if load conditions warrant reclosure. If so, the load-indicating resistor is short-circuited, leaving the lower ohmic-value load-limiting resistor in circuit. The purpose of the latter resistor is gradually to raise the feeder voltage by suitable increments.

In this way the load-limiting portion of this type of feeder serves as an accelerating resistor. The most severe condition is one where the locomotive is in full parallel outside the station and is being fed from the remote station. The difference in voltage across the open terminals of the reclosing feeder breaker, is equal to the drop in the positive and return from the remote station. Such differences in voltage may be as high as 1200 volts. Under these conditions, the reclosing feeder has to decrease this difference in voltage, by suitable steps, to zero or, in other words, raise the locomotive voltage from 1800 to 3000 volts.

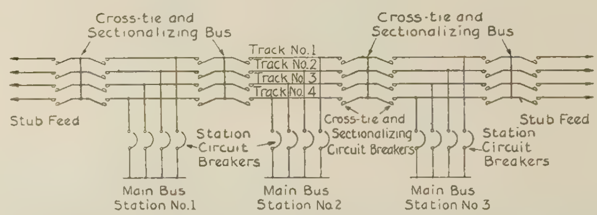

Fig. 7—Typical One-Line Diagram Showing Application of Cross-Tie and Sectionalizing Circuit Breakers

To a four-track system. Current must flow away from cross-tie and sectionalizing bus in order to trip circuit breaker on faulty section

Automatic Mercury Rectifier Substations in Chicago

BY A. M. GARRETT[1]

Associate, A. I. E. E.

Synopsis.—*Two automatic mercury-vapor rectifier substations having 3000-kw. 5000-ampere, 600-volt rectifiers are described in this paper. These rectifiers are the largest installed in this country. The reasons for the selection of this type of converting equipment instead of the rotary converter are enumerated. Information is given on the auxiliary apparatus and the control arrangement.*

THE placing in service recently of two mercury-vapor rectifier substations in Chicago, automatic in operation, marks the fourth of a series of rectifier installations in this vicinity. The application of approximately 10 rectifiers to steam road electrification service, as well as city traction supply, has perhaps made the Chicago District the representative locality for this new type of converter.

The decision to make the latest units automatic in operation was based on two fundamental reasons,

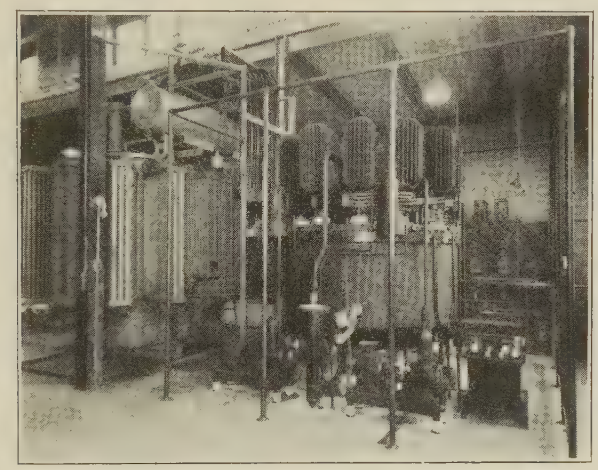

FIG. 1—3000-KW. MERCURY ARC RECTIFIER AT MAYPOLE AVENUE SUBSTATION

first, to determine whether the so called adaptability of the rectifier to automatic operation would be borne out by practical experience, and second, to demonstrate comparative performance with the automatic operation of the synchronous or rotating converter. Both types serve the same class of load supplying 600-volt energy to the elevated and surface lines systems of Chicago.

Because of the number of rectifiers of the iron tank type originally installed in Chicago or vicinity, the subsequent wide-spread interest in their performance, and the changes and additions in the latest units, making them more applicable to American practise, a word in explanation of the decision to use this type of unit for railway service is necessary.

1. Engineer of Substations, Commonwealth Edison Company, Chicago, Ill.

Presented at the Regional Meeting of the Middle Eastern District of the A. I. E. E., Cincinnati, Ohio, March 20-22, 1929.

Although from an operating point of view this decision is based upon a performance not equal as yet to that of the synchronous converter, improvements recently made in rectifiers, together with removal of handicap due to size, are some of the factors which lead us to believe the difference in reliability has practically disappeared.

The usual advantages generally understood to be characteristic of the rectifier are: a converting device simple in design and construction; practically no moving or wearing parts; low maintenance and inspection costs; absence of renewal expense and higher efficiencies. In addition, the advantages which are outstanding for rectifier installations when located in metropolitan areas are the use of water for cooling purposes instead

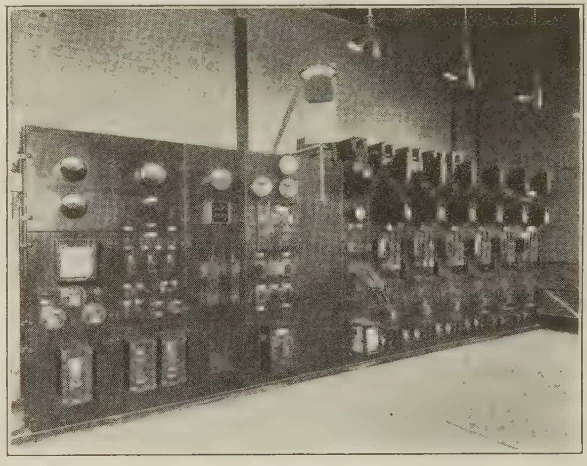

FIG. 2—CONTROL AND FEEDER SWITCHBOARD, MAYPOLE AVENUE SUBSTATION

of air, absence of noise and vibration, and the elimination of massive foundations and ventilating duct construction.

The increased number of facilities required with the installation of the modern converter of the rotating type has become a problem and a matter of concern from an operating point of view, as well as that of investment. Whether located in leased space below the street level in a commercial building, or in a substation building of the conventional type generally found in the outlying territory, the present synchronous converter must be provided with enclosures to which are

connected extensive space consuming air intake and exhaust systems, air cleaning and blower equipment, part of which is fitted in and around massive foundation work. These facilities or a modification of them must be provided for ventilation of the unit or for noise mitigation, or for both. The use of the mercury rectifier appears to be the answer to these problems which cannot be solved satisfactorily when the older type of converter is used.

The two rectifiers which are of the largest ampere size installed to date in this country, were manufactured by the American Brown-Boveri Electric Corporation. This capacity is obtained from a single cylinder arranged with 12 water cooled anodes. The rating of unit is 3000 kw. 5000 amperes, 600 volts, with 50 per cent overload capacity for two hours and 200 per cent load for one minute. Although nominally known as a 600-volt outfit, a no-load tap arrangement permits a range of voltage on the output side of the rectifier of 575 to 650 volts in steps of six full capacity taps. The rectifier which receives its a-c. energy from oil insulated self-cooled transformer is operated from the three-phase 12,000-volt, 60-cycle grounded neutral system of the Commonwealth Edison Company. The rectifier unit together with the 600-volt feeders are fully automatic, the 12,000-volt switching equipment is remote controlled from the nearest attended substation in the territory. The 12,000-volt supply to the rectifier substation is furnished in two lines arranged in a loop formation from the same attended substation.

The pump equipment for exhausting the air and gases from the cylinder is different from previous units in that two sets of pumps are used instead of one, and the mercury vapor pumps are separated from the rotary vacuum pumps, and are mounted upon the rectifier cylinder making a shorter and more effective piping arrangement with the condensing chamber.

Because the mercury rectifier is essentially a static conversion unit, devices necessary to prepare it for automatic operation are relatively few in number.

The starting of the unit is controlled by a time clock which can be set at any predetermined time to place in motion the customary control equipment commencing with the master control relay which functions in sequence to close the a-c. oil breaker, strike the ignition and excitation arcs within the cylinder, start the cooling water, and close the d-c. breaker connecting the unit to the 600-volt bus and the pick-up load that is available. Ordinarily the total time for this operation is less than one minute. To shut down the unit the master relay trips the a-c. oil breaker which through auxiliary contacts cuts off the excitation and trips the d-c. breaker. To the a-c. breaker operation is added the function of reclosing the three trials at reclosing before locking out after the third attempt.

The pumping equipment, which is used to maintain vacuum within the cylinder, operates independent of any of the other automatic functions of the unit and the control for this equipment is in operation at all times whether the rectifier is connected to the system or not, except at such times that the unit may be taken out of service for repairs or other reasons. This control consists essentially of a hot wire gage operating on the Wheatstone Bridge principle, arranged so that two of the arms of the bridge are subject to the gas pressure within the cylinder, while the other two are exposed to the pressure of the atmosphere. The difference in resistance due to difference in pressure causes a current to flow through a vacuum meter which is calibrated to indicate the vacuum directly in millimeters of mercury. This meter also carries contacts which control the action of the mercury and rotary pumps placing in operation the mercury pump only when there is a high vacuum, both mercury and rotary pumps when a medium vacuum exists, and operates the lockout relay taking the rectifier off the system when low vacuum is indicated.

The amount of water supplied to the rectifier is regulated in accordance with the load demands through the registering of the temperature of the discharge water upon a thermostatic device which in turn controls the solenoid operated water valves.

Briefly the entire installation is protected against overloads, short circuits, overheating of the rectifier cylinder, failure of the water supply, failure of the auxiliary power supply, and high-voltage surges as follows:

Overload relays of the induction type located on the high-voltage side of the transformer protect against overload and short circuit conditions. This action is selective with the d-c. breaker.

A series of continuous overloads which may occur below the setting of the overload relays and cause undue heating of the rectifier, if persisted in long enough, is guarded against by means of a thermal relay. The rectifier is further protected against overheating by a temperature relay which gives a visible warning when the temperature of the cylinder reaches 60 deg. cent. and at 65 deg. cent. locks out the substation. Protection is afforded to the equipment in case the cooling water to the vacuum pumps fails, fuses in the supply circuit to the pumps blow, or the service of the supply circuit is interrupted or fails.

Protective resistance and spark-gaps connected to the anode leads mitigate the effect of high-voltage surges.

An 8000-ampere Westinghouse carbon breaker provides the switching device for the output side of the unit, as well as protecting the rectifier against short circuit, overload, and reverse current conditions.

Further protection as to overload and short circuit conditions on the d-c. side of the rectifier including selectivity with the Westinghouse breaker is provided

by the General Electric moderate speed breakers with which each feeder is equipped. The breakers are automatic and reclosing in action.

To reduce the amount of scale forming matter which may deposit in the water passages around the cylinder due to roiled or muddy water, the cooling water is first passed through sand filters. It is expected that the amount of cleaning of the water chamber will be materially reduced.

The interior of the substation building is designed to meet the requirements of this type of conversion unit, its auxiliaries, and switching equipment. Generally the arrangement is similar to that of a rotating unit except for the absence of those features mentioned before. The exterior architecture of the building presents a structure pleasing in outline and creditable in appearance to the neighborhood.

The length of time the two units have been in service is much too short to gain any information as to operating performance. It may be said, however, that the two rectifiers were placed in service just prior to the time the heavy winter load occurs on the traction systems, and although subject to only a short seasoning period, the units have shown good performance up to the first of January, carrying at times integrated loads almost equal to the rated capacity.

Abridgment of

Lightning

Progress in Lightning Research in the Field and in the Laboratory

BY F. W. PEEK, Jr.*

Fellow, A. I. E. E.

I. Introduction

WHILE there is still much to learn, lightning may be said to be now at least on an engineering basis since it is expressed numerically in volts and amperes. It has been removed from the realm of the "medicine man."

The following indicate how rapid the progress has been: The wave shape of lightning has been pictured by the cathode ray oscillograph; the time required for a cloud to discharge has been measured by the cathode ray oscillograph; the attenuation of lightning waves traveling on a transmission line has been determined; natural lightning waves have been reproduced in the laboratory where their effects on transmission lines, insulators, insulation, transformer, and protective apparatus have been studied at will; a lightning generator producing over 3,600,000 volts has been constructed and waves from this generator have been sent over transmission lines to test full size transformers and other apparatus to determine how to make them highly resistant to lightning; scientific work on the time lag of gaps and insulation has been extended, etc.

II. Laboratory Research

The Lightning Generator. Up to the early part of 1927 the laboratory lightning work had progressed so far,[1] that it seemed important to double the 2,000,000 volts available at that time. This high voltage was desirable so that full size apparatus could be tested and results obtained without extrapolation. A 3,600,000-volt generator was built and is in satisfactory operation; and an extension is now available so that a voltage about 5,000,000 is obtainable. (On January 25, 1929, after the original writing of this paper, the voltage of the lightning generator was increased to 5,000,000 volts, and laboratory lightning research started at that potential.)

A radically new method to obtain the very high voltages was devised by the author.[2] The effect is of adding two, three, four, or more of the original generators in series at the proper instant so that all of the respective impulse voltages add together. No rectifiers are used. The a-c. voltage is applied directly to each unit generator.

Wave Shape. In the first studies of transients, wave shapes could not be pictured directly; it was necessary to calculate them. The cathode ray oscillograph[6] now affords a means by which oscillograms can be taken readily. It is interesting that these oscillograms measuring time in microseconds check the early work.[2] Fig. 5 shows a typical oscillogram. This particular wave reaches its crest in a fraction of a microsecond, and then decays to half value in five microseconds.

Sparkover of spheres, points, and insulators

The full line curves in Figs. 8 and 11 give the sparkover voltages for different gaps with the Pittsfield high voltage laboratory "standard wave" and other waves.

The effect of wave shape on the lightning sparkover

With the exception of gaps between electrodes producing a uniform field the lightning or impulse sparkover voltage is always appreciably higher than the 60-cycle sparkover voltage. The steeper the wave or the shorter the duration of the transient, the higher the crest sparkover voltage. The lightning breakdown

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1. See complete paper for bibliography.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

voltage will thus vary because lightning surges vary. The ratio of the lightning to the 60-cycle crest sparkover voltage is always greater than unity. Some years ago, this was termed the impulse ratio.[2] Under the usual severe lightning conditions in practise, insulator sparkover voltages give an impulse ratio of two. This has been well established by comparing the lightning sparkover voltages of insulators as measured in the field by

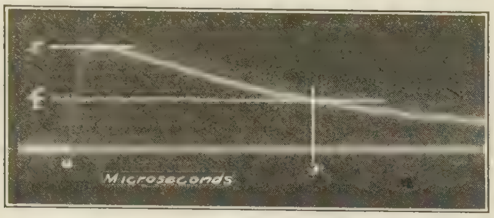

Fig. 5—Typical Five-Microsecond Wave of Lightning Generator

the surge voltage recorder and the klydonograph with the 60-cycle sparkover voltage. The impulse ratio is thus an indication of the effective duration of the wave. The wave in Fig. 7 gives approximately an impulse ratio of two. Points measured on transmission lines are indicated on one curve of Fig. 11.

Whether the front or the tail of the wave is the

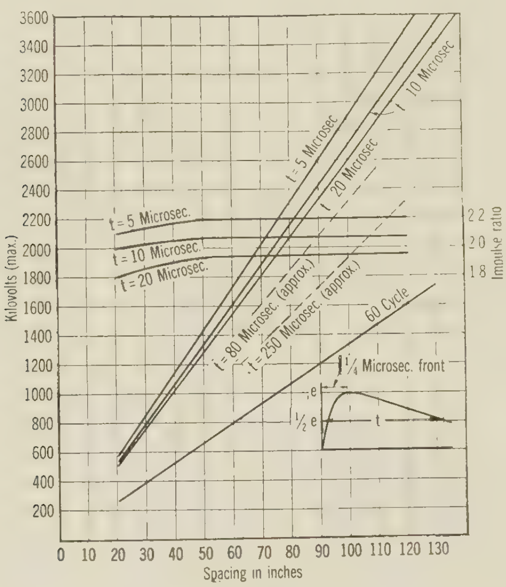

Fig. 8—Point-Gap Sparkover for Different Lightning Waves

See Fig. 5 for oscillogram of five microsecond wave.

controlling factor in determining the lightning sparkover depends upon the voltage applied. This is well illustrated in the oscillograms of Fig. 13 representing actual test records on a 19.9-cm. point-gap. The same wave shape was used throughout these tests.

Tests were also made with waves rising more or less uniformly at various rates and with breakdowns always occurring on the fronts. The results are shown in Fig. 15. For the gap used in Fig. 15, the impulse sparkover voltage approximately equals the 60-cycle sparkover when the time from application of voltage to complete breakdown is approximately 1000 microseconds. This

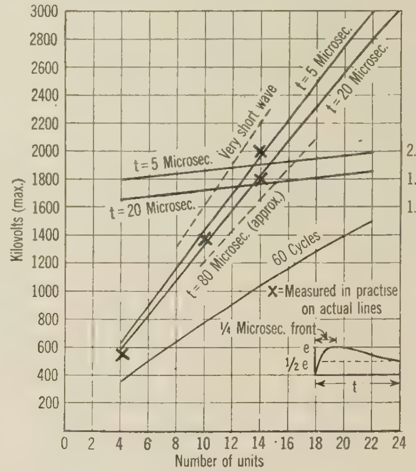

Fig. 11—Lightning and 60-Cycle Sparkover Curves of Suspension Insulators for Different Waves

See Fig. 5 for oscillogram of five-microsecond wave

shows the effect of wave-front steepness increasing the sparkover voltage as previously noted.

Standard tests in the laboratory are made by gradually increasing the impulse voltage until sparkover occurs on 50 per cent of the applications. The instantaneous breakdown voltage when the front is relatively short then depends largely upon the duration of the tail.

If the impulse ratio is the same the results on solid and liquid insulation are approximately the same whether the standard wave, the lightning wave, or a wave with a slowly rising front is used. The three waves are illustrated in Fig. 17.

When the maximum voltage of the lightning impulse

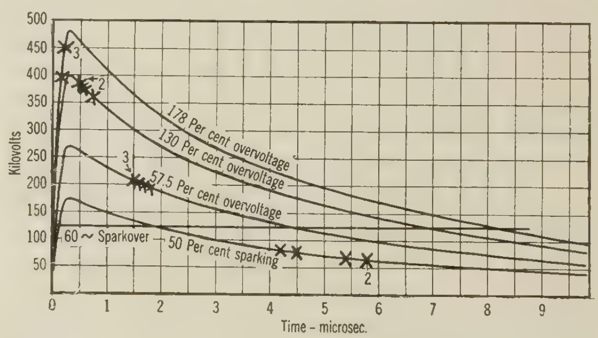

Fig. 13—Sparkover of a Point-Gap with a Constant Wave Shape at Various Applied Voltages

causing an insulator sparkover is measured by a sphere, surge-voltage recorder, or klydonograph, and the 60-cycle crest flashover voltage is known, the effective duration of the wave is also obtained. For example, the lightning sparkover of insulator strings measured in the 220-kv. lines of the Pennsylvania Power & Light Company were found to average about

2000 kv. For these insulators the 60-cycle sparkover was about 1000 kv. This indicates an average impulse ratio of 2.0. The usual impulse ratios of natural lightning varies between 1.8 and 2. The crosses in Fig. 11 for four,- ten- and fourteen-unit insulator strings are flashover voltages due to natural lightning as measured by surge voltage recorders. In a few cases, impulse ratios as high as 2.7 were obtained. These impulse ratios show that the effective duration varied from 1 to 20 microseconds, where the effective duration is the time that the voltage is above half voltage, or approximately the time above the 60-cycle sparkover. Such waves are illustrated in Figs. 5 and 7 and were actually measured by the cathode ray oscillograph. Thus, a wave giving an impulse ratio between 1.8 and 2 on line insulation represents the average severe field conditions, and the standard laboratory wave, established long before measurements were available, is confirmed as simulating practical conditions.

The above does not mean that actual lightning sparkovers are always caused by waves with fronts as

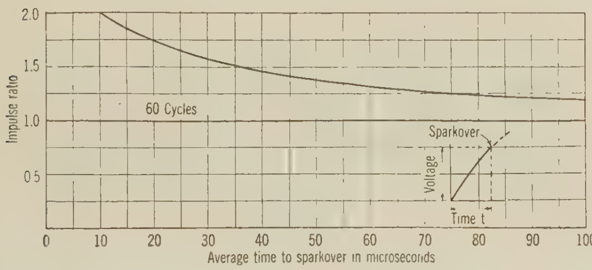

FIG. 15—SPARKOVER VOLTAGE FOR WAVES RISING UNIFORMLY AT VARIOUS RATES

steep as those in Figs. 5 and 7. In the usual laboratory tests the whole wave is used and the front has very little influence. In practise, lightning sparkovers may occur in this way or on the rising front of a moderately steep wave as illustrated in Fig. 17. If the impulse ratio is the same the results are the same. Laboratory tests are also made on the wave front.

The lightning wave secured on the Pennsylvania Power & Light Company line this last summer had a duration above half voltage of about 20 microseconds.

The grading shield. An important function of the grading shield is to cause even distribution along the string. This strengthens considerably the path along the insulator surfaces to lightning and forces the arc to take place between the rings which may be set for a lightning sparkover voltage higher than that of the non-shielded string. Destructive cascading is thus prevented. In this way the gain in voltage may be as much as 10 per cent to 12 per cent, and can be checked by comparing the lightning sparkover of the non-shielded string with the needle-gap lightning sparkover of the distance between rings. For instance the sparkover voltage of a 16-unit non-shielded string from Fig. 11 is 2050 kv. at 20 microseconds. For 85 inches (from Fig. 8) between rings, when the sparkover occurs on a shielded string, it is 2200 kv. For the 20-microsecond wave this is usually over 10 per cent for long strings. For very steep waves it may be more. The difference in sparkover voltage is not appreciable with longer waves.

While the sparkover voltage to lightning waves may be increased by the shield, the 60-cycle sparkover voltage may be lowered. This is not a handicap because lightning surges having an impulse ratio of unity and thus corresponding to 60-cycle waves have never been observed in practise. The dry 60-cycle shielded sparkover voltage might be somewhat increased by using *very* large shield surfaces free from sharp ends or points. However, there can be no gain in practise in this way because the large surfaces would be reduced to equivalent "points" in 60-cycle voltages when wet by the first raindrop. Lightning sparkover voltage is not affected by rain.

That shields prevent deterioration of the units in a string through improved distribution of voltage stresses is forcibly illustrated in tests. After a few lightning sparkovers, insulator units fail in the non-shielded strings while there are no failures in the shielded strings.

In addition to the actual increase in lightning sparkover voltage discussed above, there is also an apparent increase which is probably of more importance. When the energy of the lightning generator is limited, it is necessary to supply a higher voltage to a shielded string to cause sparkover. This apparent increase in sparkover voltage may be of a higher order than the actual increase. The extra voltage must be generated because of the energy dissipated by the "barrel" of corona arcs between the edges of the rings. The gain has been observed when the energy available approximated that in an average span and should be an approximate measure of the effect in practise since there is one shield for each line per span. This energy dissipating effect by corona has been made use of by purposely designing grading rings of flat strap material in place of smooth surfaced pipes.

Wood poles The insulating value of a wood pole to lightning voltages has been measured up to 3,600,000 volts. The measurements show that the strength of wood poles of such varying degrees of wetness and dryness as might occur in practise, range from 100 to 300 kv./ft. A good average value is 180 kv./ft. With a lightning rod a part of the insulation of the pole could be utilized and protection from splitting afforded at the same time by placing a gap in series with the lightning rod. (See complete paper for gap dimensions).

Transformers. The new lightning generator has made possible invaluable studies on full size transformers and insulation arrangements.

Cathode ray oscillograph records of surges on trans-

formers are taken and the voltage distribution is measured throughout the winding. This last measurement is of extreme importance since it shows that in the usual transformer the voltage distribution is not constant but varies with steepness and duration of the impulse or the frequency of the transient. High frequencies and steep impulses may cause excessive voltages at any part of the winding. The ideal transformer would be one in which the voltage distribution was the same for all frequencies and wave shapes. Fortunately it has been possible to accomplish these results by the shielded design, which is an entirely new type. It will not be necessary to go into details here as this transformer is described elsewhere.[8] Fig. 24 shows the results of tests on an actual transformer. In the shielded transformer the impulse and high frequency distribution is shown to be practically the same as the 60-cycle distribution.

Briefly, the reason for the varying distribution of voltage in a non-shielded transformer is as follows: The initial lightning distribution is determined by the distribution of the capacity in the windings and the 60-cycle or long duration voltage distribution by inductance. If the voltage distribution as determined by these factors is not the same an oscillation results until the distribution corresponds to that of the inductance. The shields make the capacity and inductance distribution correspond. The action of the capacity is instantaneous and there is no oscillation.

III. Field Research

Research on Transmission Lines

During the past few years a number of the operating companies in collaboration with the manufacturing companies have obtained some very important measurements, particularly of lightning voltages on transmission lines.[9,10] These measurements were obtained with the klydonograph or surge voltage recorder connected at various points along the transmission lines.

Very valuable data was accummulated which gave further information as to the voltage, polarity, wave shape, and attenuation of lightning waves on lines. The general nature of the waves was briefly as follows: The maximum voltage found was about 2800 kv.; in general, most high-voltage surges indicated negative cloud discharges, although a few obtained indicated positive strokes; the impulse ratios of the waves were around 2.0, and the effective durations—that is, the time the waves were above half voltage—were from one to twenty microseconds; the attenuation was very rapid, particularly for the very high crest voltages where excessive corona would exist—for example, it was found that a 3000 kv. wave would be reduced to half value in traveling about two miles.

Measurement of Lightning Waves and Time Required for a Cloud to Discharge with the Cathode Ray Oscillograph

In order to make proper use of the oscillograph, it was necessary to devise a means of establishing the cathode beam and the sweeping circuit and to have the complete set-up connected to the line as the lightning wave reached it. With the equivalent "switching circuit" developed for this, the complete operation was accomplished in about one microsecond—that is, one-millionth of a second.

(*a*) *Pittsfield measurements.* In the Pittsfield measurements the antennas consisted of three parallel wires 120 ft. long and 40 ft. above ground. The wires were grounded through a 2,000,000-ohm resistance, and connection to the oscillograph was made. With this arrangement the lines assume a potential opposite to that of the cloud when the lightning discharge takes place. Since the charge cannot move along this short line, but must be dissipated by leakage, the potential of the conductors rises at a rate and to a magnitude dependent upon the collapse of the cloud field. The time for this conductor voltage wave to reach maximum is thus a measure of the time required for the cloud to discharge. Fig. 27 shows two of the four antennas waves obtained. The wave fronts are

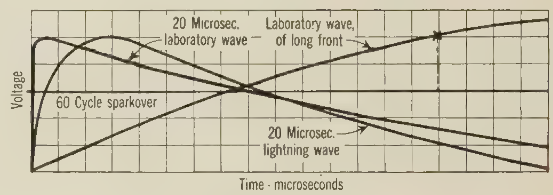

Fig. 17—Sparkover Voltage for Various Waves

of the order of one to two microseconds. The induced voltage crests on the antennas were from 50 to 75 kv.

(*b*) *Pennsylvania measurements.* A very good natural lightning wave obtained on the 220-kv. line is shown in Fig. 28. The front of this wave practically reaches its maximum in 5 microseconds, decreases to half value in 20 microseconds, and reaches zero in 40 microseconds. The oscillating ripple is apparently due to a local flashover[12] and is not really part of the original wave. A reproduction of this wave by the laboratory lightning generator is also shown in Fig. 28. The effects of the wave are very similar to the standard wave of Fig. 7 and the impulse ratio for insulator sparkover corresponds to those determined by the surge recorder or klydonograph readings.

IV. Lightning on Transmission Lines and Apparatus

Voltage

The available data still confirm the rule that the maximum induced voltage on a transmission line depends upon the height of the conductors above ground or

$$V = h\,g\,\alpha$$

Where V = volts, h = average height of conductor in feet, and α depends upon rate of cloud discharge and the initial distribution of bound charge on the line.

Calculations indicate that under the usual assumed bound charge conditions, an induced voltage wave high enough to cause insulator flashover can result only from a rapid collapse of the electrostatic field of the cloud. Accordingly, this must involve a traveling wave

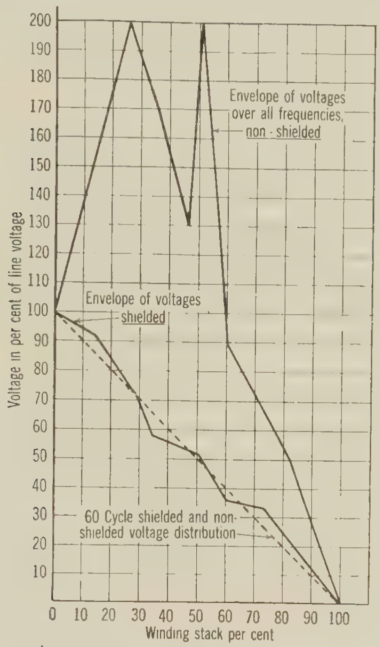

Fig. 24—Voltage Distribution at all Frequencies of Shielded and Non-Shielded Transformers

of steep front or of short effective duration. A steep wave front would also occur with a surge imposed on a conductor by a direct stroke to it. The maximum voltage wave that can travel on the line and reach the apparatus is determined by the line insulation. The waves in practise are generally non-oscillatory and have a wide variety of shapes. However, the waves usually causing insulator sparkover give an impulse ratio of the order of two (2.0), and indicate an effective

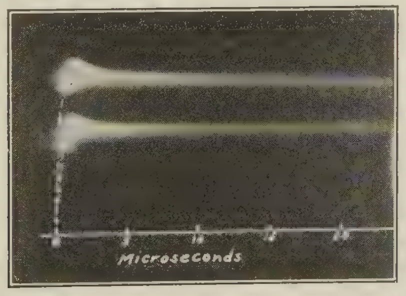

Fig. 27—Oscillogram of Natural Lightning Made on Short Lines—Pittsfield 1928. Drawn Dotted Lines Indicate Approximate Fronts

duration of 1 to 20 microseconds above the 60-cycle flashover value.

The Ground Wire. Statistical data still confirm the value of the ground wire. These data indicate that outages due to insulator arc-overs are reduced from one-half to one-tenth or more after the installation of the ground wire.

Lightning Proof Transmission Lines and Coordination of Transformer Insulation and Line Insulation

The ideal line would be as low in height as practicable, be protected by one or more ground wires, and be well insulated with insulators protected by grading shields. The transformer insulation should be somewhat stronger than the bushing flashover voltage, which in turn should be higher than the flashover voltage of the insulators in the immediate vicinity of the line. By immediate vicinity is meant that the coordinated insulation should start within 75 ft.

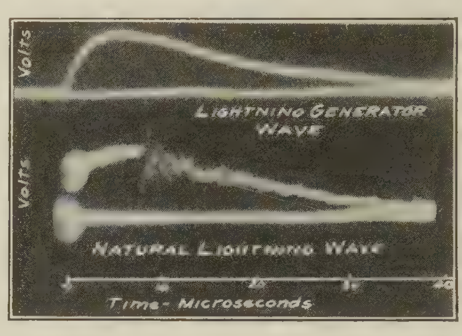

Fig. 28—Comparison of Natural Lightning Wave Measured on Transmission Lines with Cathode Ray Oscillograph with an Artificial Lightning Wave Measured in the Same Way

of the apparatus and preferably extend out at least one-half mile. Such arrangement of the insulation should not increase outages. As a precaution, extra ground wires may be added on the coordinated section to provide against local disturbances. However, where the line is badly exposed to direct strokes special precaution should be taken in the design of the tower so that side flashes are not likely to take place from ground wire to conductor. Rods might be used and special precautions taken as to length of span, ground resistance, distance from conductor to ground wire, etc. Extra ground wires in sections may be necessary to assure immunity against direct strokes.

FARADAY CENTENARY IN 1931

Preliminary plans for the celebration of the centenary in 1931 of Faraday's epoch-making discoveries are reported by the *Electrical World* to have been made in London at a meeting of representatives of scientific, electrical and other societies held at the Royal Institution under the presidency of Sir Arthur Keith. The time chosen provisionally for the celebrations was the third week in September, 1931, and it was decided to set up two small committees, representing the scientific and industrial interests, to make the necessary plans and to insure that the celebrations shall be attended by interested persons from all parts of the world.

Bushing-Type Current Transformers for Metering

BY A. BOYAJIAN[1] and W. F. SKEATS[2]

Fellow, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*This paper describes a new development in connection with bushing type current-transformer metering circuits. While this development utilizes the two-stage principle and has the same order of accuracy as that of two-stage current transformers, it is different from the conventional two-stage current transformers in that it does not require two-stage wattmeters and watthour meters, but may be used with any wattmeter or watthour meter. The principle and connections of the transformer are explained, and performance curves of a typical unit are given.*

* * * * *

Introduction

The great simplicity, reliability, and low cost of the bushing-type current transformer have led engineers to an effort to improve its accuracy to such a point as will be satisfactory for metering purposes. The introduction of the two-stage principle[3] by Brooks and Holtz, six years ago, marked a satisfactory improvement in accuracy, but the two-stage principle as applied so far has required special two-stage wattmeters and two-stage watthour meters. There has still remained, therefore, the need for a bushing-type current transformer that would have metering accuracy and could be used with any wattmeter or watthour meter. In the development of the arrangement described below, which satisfies this requirement, the two-stage principle has been retained and such additional features have been incorporated as would make it adaptable to single-stage wattmeters and watthour meters.

Circuit of the New Current Transformer and Theory of Its Operation

Fig. 1 illustrates diagrammatically the conventional two-stage current transformer and a two-stage wattmeter or watthour meter. $P_1 S_1$ is the first stage of the current transformer feeding the first-stage current-coil C_1 of the meter W. The current in C_1 differs (vectorially) from the correct secondary current by the exciting current in P_1 divided by the turn ratio of the transformer. The second-stage transformation aims to put into C_2 a current equal to this difference. In the second stage of this current-transformer, P_2' and P_2'' act jointly as the primary; that is, the net ampere turns of P_2' and P_2'' act as the primary ampere turns, inducing a corresponding secondary current in S_2, which flows into the second-stage current-coil C_2 of the meter. The net ampere turns of P_2' and P_2'' are the exciting ampere turns of the first stage and thus the current delivered to S_2 and C_2 represents and makes up for the exciting current error of the first stage. In transforming the exciting current of the first stage, the second-stage current transformer requires an exciting current, so that the exciting current correction by the second stage is not 100 per cent exact. However, since the residual error is the exciting current of the exciting current, it is of second order of magnitude as compared with the error of the first stage or as compared with the error of an ordinary current transformer of the same proportions.

In order that the two stages may perform without interference from each other, it is necessary that the two circuits have no appreciable mutual impedance.[4] One obvious method of accomplishing this is to separate the current coils C_1 and C_2 from each other and provide a separate potential coil for each one to react with.

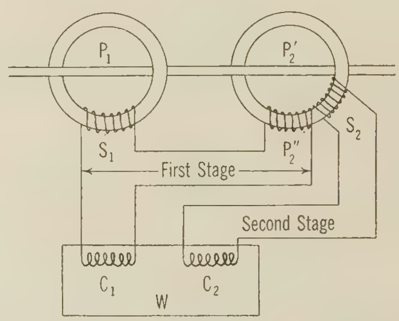

Fig. 1—Two Stage Current Transformer with Special Wattmeter Having Two Current Coils

This is the practise followed in most of the two-stage current transformer applications, requiring special wattmeters and watthour meters. This disadvantage has been obviated in the present arrangement as follows:

For the proper performance of the two stages, it is not necessary that there should be no mutual impedance between the two circuits at any point, but that there should be no *net* mutual impedance. Accordingly, C_1 and C_2 may have any mutual impedance at any point provided that it is neutralized by an equal and opposite mutual impedance at another point. If C_1 and C_2

4. By the mutual impedance between two circuits is understood the ratio (vectorial) of the voltage in one circuit produced by current in the other to the current flowing in the other circuit. As far as the authors know, this conception has to date been limited to mutual inductance or mutual reactance, but if the two circuits have a part in common it is obvious that current flowing in the one will give rise to an in-phase voltage in the other due to the resistance of the common part.

1. General Electric Company, Pittsfield, Mass.

2. General Electric Company, Schenectady, N. Y.

3. See *The Two-Stage Current Transformer*, by H. B. Brooks and F. C. Holtz, A. I. E. E. Trans., 1922, p. 382.

Presented at the Regional Meeting of the Middle Eastern District of the A. I. E. E., Cincinnati, Ohio, March 20-22, 1929.

are combined into a single current coil C (Fig. 2) as in any conventional wattmeter or watthour meter, the mutual impedance between the first and second stage circuits is the impedance of the coil C, and therefore it is necessary and sufficient to provide another impedance common to the two circuits and equal and opposite to C. This is accomplished by the auxiliary impedance Z and the transformer T. The impedance Z is substantially equal to the impedance C times the ratio of transformer T, and the transformer T accomplishes the desired reversal of sign so that one can neutralize the other. To make this clearer, assume that the switch A in the second stage is opened. The first stage current flowing through C and the primary T, will naturally circulate a corresponding current in the secondary of T through the impedance Z. If now we trace the second-stage circuit beginning at a and ending at b, through Z and C, we find that there are two impedance drops in it, one at Z, the other at C, and that these two are opposite to each other so that no net voltage appears from a to b induced from the first stage current. The equality of the two drops is accomplished by the equality of the two impedances, while the opposition of the drops is accomplished by the fact that the secondary induced current of T must be opposite to its primary current. Thus, the net mutual impedance between the first-stage and second-stage circuits is rendered zero; and, therefore, if the switch A is closed, the second-stage current transformer delivers its current into the current coil C of the meter unaffected by the first-stage current C. Thus, both the first and the second stage currents flow simultaneously in one and the same coil C without any interference.

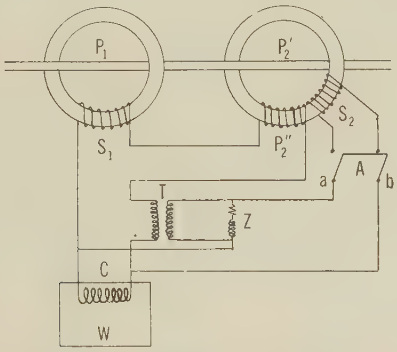

Fig. 2—Two Stage Current Transformer with Standard Wattmeter

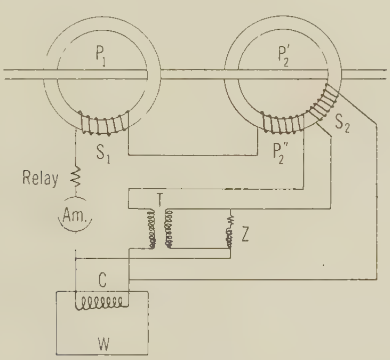

Fig. 3—Two Stage Current Transformer with Standard Wattmeter, Ammeter, and Relay

If Z is vectorially identical with the impedance of C, obviously the exciting current of T will cause the drop across Z to be slightly (vectorially) different from that across C. This error may, if desired, be compensated by making Z proportionately (vectorially) different from C. The magnitude of this error, however, is very small compared with the general improvement accomplished, especially in the bushing-type current transformers; because, first, the auxiliary transformer T is a very low-voltage transformer and can therefore be made far more accurate than the high voltage units P_1, P_2; and second, the auxiliary transformer T need not be bushing type, but of any high accuracy type, and thus again its error will be almost negligible for the circuit conditions. T is not to be mounted on the bushing but at any convenient point on the switchboard near the meters.

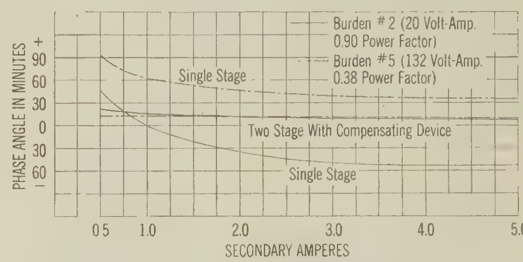

Fig. 4a—Performance Curve

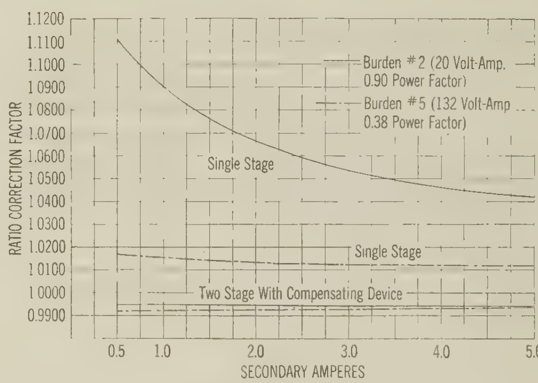

Fig. 4b—Performance Curve

Fig. 3 illustrates the connections of such a current transformer arrangement with a number of instruments. Since great precision is necessary only in the meters and not in the indicating instruments or relay coils, only the watthour meter is shown included in the second stage. This leads to greater accuracy by reducing the burden and exciting-current of the second stage. In such applications, the auxiliary impedance Z must obviously represent the impedance of only that part of the burden which is to be "two-staged." The

auxiliary impedance naturally adds to the burden of both stages, but since it duplicates only that part of the burden which is to be "two-staged," it adds only a small amount to the total.

Performance Curves

Figs. 4A and 4B show performance curves of a 300-ampere turn, 60-cycle unit designed for a 132-kv. bushing. Single stage curves taken on the same unit, and using both first stage and second stage iron are also shown for comparison. The curves were taken for standard burdens No. 2 (20 volt-amperes, at 0.90 power factor) and No. 5 (132 volt-amperes, at 0.38 power factor). It will be noted that errors in phase angle of + 36 min. and − 52 min. at full load have been reduced to + 10 min. and + 8 min. respectively, whereas errors in ratio of 4.2 per cent and 1.2 per cent have been reduced to 0.6 per cent in each case. Moreover, whereas the uncompensated transformer showed much larger errors at low values of current than at high values, the two stage transformer with the compensating device is very nearly as accurate with 0.5 secondary amperes as with 5 secondary amperes.

Table I shows the final correction factor for each burden at 0.5 secondary amperes and at 5.0 secondary amperes and at various power factors.

The table shows that the combined ratio and phase angle error changes from 1.1 per cent at 10 per cent of rated secondary amperes to 0.8 per cent at full rated secondary amperes at 80 per cent line power factor, with additional improvement as the power factor is increased.

TABLE I
FINAL CORRECTION FACTOR

Line power factor	0.5 secondary amperes		5.0 secondary amperes	
	Burden No. 2	Burden No. 5	Burden No. 2	Burden No. 5
0.90 lead	0.994	0.997	0.995	0.995
0.95 lead	0.993	0.996	0.995	0.995
1.00	0.992	0.994	0.994	0.994
0.95 lag	0.991	0.992	0.993	0.993
0.90 lag	0.990	0.991	0.993	0.993
0.80 lag	0.989	0.989	0.992	0.992
0.70 lag	0.988	0.987	0.991	0.992
0.60 lag	0.987	0.985	0.990	0.991
0.50 lag	0.985	0.983	0.989	0.990

The Post College Education of Engineers

BY EDWARD BENNETT[1]

IN the fact-finding stage of the studied movement to "develop, broaden, and enrich engineering education" which has been sponsored by the Society for the Promotion of Engineering Education, the experiences and opinions of practising engineers have been an essential and an important contribution to the study. The study has resulted in a wealth of carefully analyzed information pertaining to the objectives of engineering education, to educational practises and results, and to the possible methods of broadening and enriching educational procedures.

The complete working out and the full realization of some of these possibilities will require the cooperation of the three groups represented on the Institute's Committee on Education, namely: the engineering practitioners, the engineering teachers, and the engineering industries. Under these conditions, it has seemed to the Committee that it is confronted with the opportunity to advance those educational movements requiring the cooperation of these three groups. The Committee has deemed it wise to concentrate its efforts upon a single movement rather than to spread them over several.

Of all the undeveloped educational movements requiring the cooperation of the practitioners, the teachers, and the industries, none seem to the Committee to have greater possibilities of advancing the standards of professional achievement than does the movement to stimulate the continuation of education after college, and to make provision for this post college education.

The continued rapid increase in scientific knowledge and the rapid increase in the diversity and complexity of the engineering applications and the engineering responsibilities combine to make the four year engineering program a less and less adequate preparation for effective engineering work. The S. P. E. E. study has disclosed that very few engineers or teachers propose to meet this situation by requiring all college students to remain upon the college campus for a fifth or sixth year. The solution seems to be rather, to encourage that limited number of graduates which is possessed of the requisite interest and means to enroll in resident graduate courses, as well as the greater number who enter at once upon their engineering apprenticeships, to continue their educational efforts to a greater extent and to a more definite end than at present.

"Is not this field of post college education one of primary responsibility of the professional body? The tradition of the profession has always been that college training is only a part of an engineer's preparation, and that experience in subordinate capacities, under the direction and criticism of qualified practitioners, is an indispensable part of his training," and yet the engineering profession has assumed no responsibilities with reference to this post college training.

1. Chairman, Committee on Education.

The teaching profession assumes the responsibility for only the first part of the engineer's training; the larger industrial organizations have assumed and are assuming greater responsibilities during the period of their apprenticeship courses. Should the engineering profession leave the post-college training entirely to chance, circumstance, and the industries? "Could the profession define in terms that are flexible enough to avoid making a straight jacket and yet explicit enough to be of value, what it expects of the young electrical engineer in addition to his scholastic training in school and college? Could this further training be backed up by some incentive and be given some distinctive recognition? Could the way be prepared for some review of the entire early education and experience of the young engineer—say five years after he is graduated—as a basis of professional certification? Could this plan of certification be tied in as a form of joint sanction with the award of the professional degree by the colleges?"

Considerations and questions such as those recited above lead the Committee to feel that it can render the most effective service,

(a) by seeking to bring the thought of the Institute membership to bear upon the possibilities and the problems of post-college education and upon the responsibilities of the profession relative to this period of training;

(b) by seeking to stimulate the local sections to promote this movement by setting to work to canvass or inventory the post-college needs and the educational facilities of their districts, bringing the two together;

(c) by seeking to act as a center through which a knowledge of distinctive and effective developments in the field of post college education may be made generally known.

The section of the Investigation of Engineering Educations of Bulletin 3 entitled the Continuation of Education After Leaving College contains the following suggestions as to the services and types of courses which the colleges may make available for the purpose of post college education.

1. The colleges may make well outlined reading courses available to such graduates as apply for them.

2. Certain institutions, if properly manned and organized, may offer correspondence courses. Subjects such as contracts and specifications; industrial organization and planning; commercial methods, organizations and law; cost accounting; and financial methods lend themselves to instruction by this means.

3. In certain cases, extension courses for graduate students may be set up in industrial centers in which graduates in particular fields can confer with representatives of the institutions at regular intervals. Post-scholastic courses of the following types may be offered:

(a) Advanced work of the kind given in post graduate residence courses in mathematics, physics, and engineering subjects.

(b) Courses dealing with recent developments, designed to enable graduates to keep abreast of scientific progress.

(c) Seminars for the discussion in the light of fundamental theory of

(A) Allied research problems,

(B) Allied or common design problems,

(C) Allied or common operating or manufacturing problems.

4. The engineering colleges may undertake individually to furnish advisory services to alumni and other engineers in the vicinity of the colleges to assist in such matters as:

(a) Recommended reading courses.

(b) Supplying information as to educational facilities available in the community in which the graduate is located.

(c) Advice and suggestions relative to engineering problems of the kind rendered to students in residence who are engaged in thesis projects.

In addition to the possible post college services rendered by the colleges alone, which are listed above, the following types of courses should be listed.

1. Advanced studies under the joint auspices of the colleges and the industrial organizations; as, for example, the arrangements between the University of Pittsburgh and the Westinghouse Electric and Manufacturing Company, or between the Massachusetts Institute of Technology and the General Electric Company, or between the Bell Laboratories and Columbia University.

2. Advanced and special technical training of an organized character given under the auspices of the employing organization; such as the out-of-hours courses of the Bell Telephone Laboratories, or the design courses of the Westinghouse and General Electric companies.

3. Training courses designed to give familiarity with the organization and practise of a particular company or industry given under the auspices of the employing organization.

For further information relative to the experience which has been had in the field of post college education, any one interested may consult Bulletin 3, (referred to above) or a paper entitled *Seminars for Practising Engineers*, by Edward Bennett, of the TRANSACTIONS of the A. I. E. E. for 1926, Vol. 45, p. 602 or an address entitled The Urban University and Engineering Education* delivered by H. P. Hammond before the Association of Urban Universities November 16, 1928 and reciting the striking results of the recent venture of the Brooklyn Polytechnic Institute into the field of post-college education.

In view of the ends which the Committee is seeking to attain, the chairman has one recommendation which he wishes to make and to urge upon the attention of the Sections at this time. It is that the Sections, particularly in the industrial centers in which Colleges of Engineering are located, each appoint a Committee on Education. It is suggested that the function of the Section committee on education be to canvass the needs and the wishes of the engineers of the district, particularly the younger engineers, and to make these needs and wishes articulate by bringing them to the attention of the college administrations, or the industrial manage-

*Printed in *Milwaukee Engineering*, Vol. IX, Nos. 4 and 5, Jan. and Feb. 1929.

ments, or the engineering authorities in the district, in the form of explicit statements such as the following: Consider a group of 20 men who will enroll in a course in differential equations, to meet one evening a week for a year; or 15 men who will enroll in a course in Advanced Circuit Theory; or 30 men who will enroll in a course in Engineering Economics. What provision can be made to meet the needs of these men?

It is suggested that the local Committee on Education, making its announcements through the Section, the affiliated societies of the district, and through the local press, hold a special meeting or meetings to bring to the attention of those interested the post-college educational opportunities of the district, and to canvass the desires and the purpose of those attending the meeting to embark upon specific lines of work.

In preparing this message for the Committee, the chairman has quoted freely from the letters of other members and from the Bulletins of the Investigation of Engineering Education. The Committee solicits the opinions and the experience of the profession relative to the post-college training period.

Abridgment of

132-Kv. Shielded Potentiometer

For Determining the Accuracy of Potential Transformers

BY C. T. WELLER[1]

Member, A. I. E. E.

Synopsis.—*The potentiometer principle is well understood. Its application to the determination of the ratio and phase-angle accuracy of potential transformers is not new, but in unshielded form has been limited to about 66 kv. and in shielded form to about 33 kv. The paper describes a shielded potentiometer for 132 kv., which is designed for ultimate extension to 220 kv.*

Introduction

THE first potentiometer used in the General Electric Laboratory for determining the ratio and phase-angle accuracy of potential transformers was described in 1909. This "deflection" potentiometer was rated at 33 kv. and remained in service until 1920. By that time many 66-kv. potential transformers had been built so that it became necessary either to extend the voltage range of the potentiometer or to abandon the early policy of having equipment available for testing at full rated voltage. A second potentiometer rated at 66 kv., and differing from the first principally in the type of resistors used, was built and put into operation; but even this greater range soon became inadequate. The accumulated experience showed that the general scheme employed was entirely satisfactory but that a further extension of the voltage range would necessitate radical changes in the construction and arrangement of the resistors, principally to secure better dissipation of heat and to permit shielding against capacitance to ground.

In order to make further extension possible in 1924, the author proposed to construct 100,000-ohm resistor units of fairly large dimensions, rated at 11 kv. each, and to maintain the respective unit shields at the proper potentials by means of a special auto-transformer (in separate sections) of ample rating with suitable taps. Four of the units and one auto-transformer section constitute a complete 44-kv. group; the number of series groups necessary is determined by the voltage range desired. To the best of his knowledge, the proposed arrangement and method of shielding had not been utilized before. The 132-kv. potentiometer herein described incorporates the proposed features.

Objective

The potentiometer desired was one which would (1) cover the range from 6.6 to 132 kv. at first and to 220 kv. by future extention, and (2) conform as closely as practicable to an ideal potentiometer over the entire range.

An ideal potentiometer should incorporate the following features:

a. The d-c. resistance of the unit(s) obtained by means of a low-voltage bridge should remain constant and should equal the a-c. effective resistance at operating voltage.

b. The current in all parts of the resistor(s) should be exactly proportional to, and in phase with, the line voltage.

c. The flexibility required should be obtainable without excessive complications and without sacrificing convenience of operation.

Summary

The installation of three 44-kv. series groups and accessories at Pittsfield was completed in 1928. The

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1. General Engineering Laboratory, General Electric Company, Schenectady, N. Y.

2. *Electrical Measurements on Circuits Requiring Current and Potential Transformers*, by L. T. Robinson, A. I. E. E. Trans., Vol. 28, 1909, p. 1005.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

groups alone occupy about 380 sq. ft. (42 ft. by 9 ft.) of floor space, have a height of approximately 12 ft. and weigh about 65 tons (the first potentiometer complete weighed less than one ton). A "General Description" of the potentiometer is given under that title.

Potential transformers have been tested for accuracy over the range from 6.6 to 132 kv. at 25 and 60 cycles (see comments under "Test Results").

Compared with the ideal outlined:

a. The d-c. resistance of the units is practically constant and agrees with the a-c. resistance within 0.01 per cent.

b. The current in the units is directly proportional to the line voltage at all points but small phase displacements exist. The "net" phase angle of the current at 60 cycles ranges from approximately − 1′ (leading) at 6.6 kv. to − 7′ at 44 kv. in the first group, to − 6′ at 88 kv. with two groups, and to − 4′ at 132 kv. with three groups; the corresponding corrections have the same signs.

c. Transformers rated between 6.6 and 44 kv. in 1.1-kv. steps (with a corresponding increase in ratio) and between 44 and 132 kv. in 5.5-kv. steps can be tested; this includes practically all standard ratings. Odd ratings differing less than 4 per cent from those indicated can be tested without special adjustments, but other odd ratings require an adjustment of the resistance. The ratio (correction factor) is read directly (or by interpolation) for standard ratings but must be calculated for odd ratings; the phase angle is calculated from instrument deflections in all cases.

The complications are not excessive, and the operation is reasonably convenient; provision is made also for operating with the mid-point instead of with the lower end of the potentiometer grounded.

The twelve resistor units and the three auto-transformer sections or shielding transformers are interchangeable respectively.

Conclusions

The accuracy obtainable is sufficient to permit certifying results to within 0.1 per cent in ratio and to within five minutes in phase angle over the entire range; these limits are in accord with our best previous practise.

The potentiometer can be extended to 220 kv. without making radical changes in any of the groups whenever the demand justifies it.

Principles of Operation

The principles of operation of our "deflection" potentiometers, which in comparing voltages utilize deflections as well as null or zero instrument readings, have been described[3] but are again outlined in the complete paper.

Effects of Capacitance

All potentiometer resistance used has been of manganin wire non-inductively wound and immersed in oil. Troublesome resistance changes and appreciable inductance were eliminated. The effects of capacitance are indicated in Fig. 2, and are outlined in the complete paper.

3. L. T. Robinson, *Loc. cit.*

General Description

The 132-kv. shielded potentiometer combines potentiometer resistance suitable for alternating current with shielding transformers and other special auxiliary equipment. In connection with standard power-supply equipment, it is arranged for use in determining the ratio and phase-angle accuracy of potential transformers rated from 6.6 to 132 kv., 25 to 60 cycles and 25 to 1000 volt-amperes, respectively.

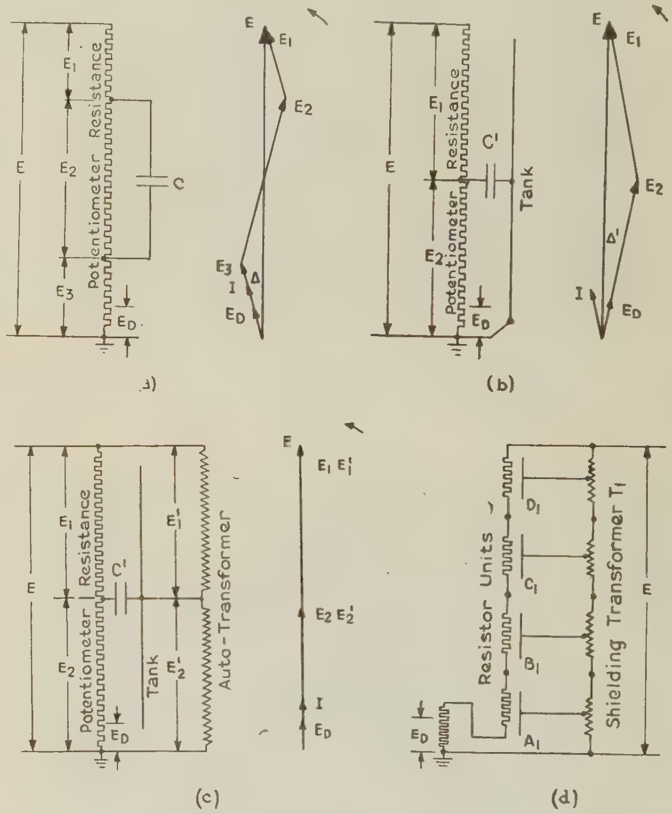


Fig. 2—Effects of Capacitance

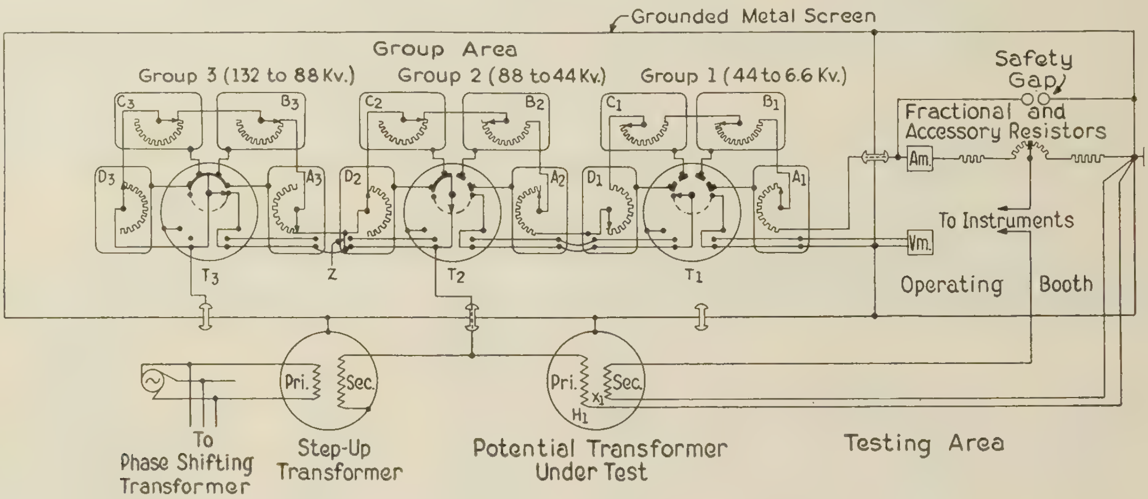
(a) "Internal" capacitance between sections
(b) "External" capacitance to tank (ground)
(c) Elimination of effect of (b) by means of an auto-transformer
(d) Schematic arrangement of 44-kv., Group No. 1

The potentiometer is shown schematically in Fig. 3A and B and directly in Figs. 6 and 7. The three 44-kv. series operating groups, each consisting of four 100,000-ohm resistor units and one shielding transformer, occupy about 380 sq. ft. (42 ft. by 9 ft.) of floor space and have a maximum height of about 12 ft., 3 ft. of which is due to the Herkolite insulating cylinders. The group area contains about 900 sq. ft. (52 ft. by 17.5 ft.); part of the grounded wire mesh which acts as an electrostatic screen for the groups is buried under the floor, while the remainder forms a fence 20 ft. high on the four sides of the area. The supply voltage is brought in from the

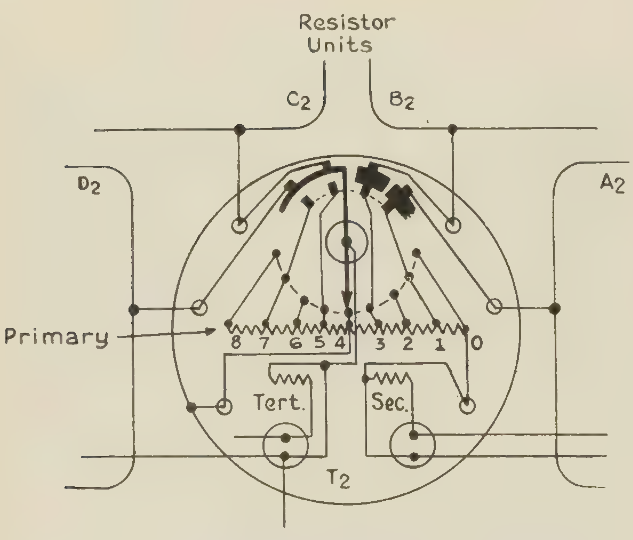
testing area through high-voltage bushings. The metal and glass operating booth is about 16 ft. square and 8 ft. high. It contains the fractional and accessory resistances and all instruments and control equipment. Approved safety devices are used wherever necessary.

Resistors. The potentiometer has a total resistance of 1,200,000 ohms and is rated at 0.11 ampere. The resistance is divided into three 400,000-ohm operating groups, which are subdivided into four 100,000-ohm units. From the construction standpoint the 100,000-ohm interchangeable units are basic; they are made up of ten 10,000-ohm sections, which are in turn made up of twelve 833.3-ohm tubes each; construction details are shown in Figs. 4 and 5. The arrangement and ratings are summarized in Table I. A more "Detailed Description," which includes the fractional (normal value-1000 ohms) and accessory resistance, is given under that title.

Shielding Transformers. The three interchangeable shielding transformers (one for each 44-kv. group) are rated as follows: 25 cycles, 75 kv-a., 50,000, 500/500 volts. (The maximum voltage rating for the three primary windings in series is 150 kv.) Since their function is to equalize the flux density and voltage distribution in the transformers when either two or three are operating in series the secondary and tertiary windings are considered as equalizing windings; the connections are indicated in Fig. 3A and B. Each transformer has eight primary taps and nine bushings, one of which supports the somewhat complicated tap switch. The four unit tanks are connected to four of the bushings and from them to the proper transformer taps by means of the switch and thus maintained at predetermined potentials.



(a)



(b)

FIG. 3—132-KV. POTENTIOMETER—66-KV. CONNECTION (SCHEMATIC)

(a) General outline
(b) Shielding transformer T_2 in Group No. 2

TABLE I
ARRANGEMENT AND RATINGS OF POTENTIOMETER RESISTORS

Item	Rating		Number Required	
	Ohms	Kv.	Per Step	Total
Tube........	833.3*	0.092	12 per Section	1440
Section......	10,000†	1.1	10 per Unit	120
Unit........	100,000	11	4 per Group	12
Group.......	400,000	44	3 for 132 kv.	3
3 Groups....	1,200,000	132		

*Approximate adjustment—rated at 0.11 ampere (9.09 ohms per volt) nominally, 0.125 ampere maximum.
†Adjustment correct within 0.02 per cent.

Operation. In operating, the total resistance used in each case is obtained by setting the tap switch on the 100 per cent tap in each of the 100,000-ohm resistor units up to the unit in which the final setting is made, all or only part of the resistance of this unit may be required—(ten equal steps are obtainable with the tap switch but only the 100 per cent and 50 per cent taps are, in general, used above Group No. 1); the tap switch

is set on the zero tap in each of the 100,000-ohm units beyond the unit in which the final setting is made. The correctness of the setting is then checked by a bridge measurement; this procedure is independent of the number of units used, since all units are connected in series; however, connection is made to the upper end of the highest group involved. The connections for 600,000 ohms or 66 kv. are indicated in Fig. 3A; the connection Z between the resistance and shielding transformer circuits is opened for the bridge measurement; the 0.2-ampere ammeter, Am, gives an approximate indication of the operating current.

The shielding transformers are excited magnetically only when one or more resistor units in their respective groups are in use. In Group No. 1, transformer T_1 is excited on tap No. 6 (nominally 33 kv.) for voltages between 6.6 and 30.8 kv. to obtain a minimum phase angle; taps No. 7 and 8 are used for higher voltages up to 44 kv. One lead between the tertiary of T_1 and the secondary of T_2 is opened, (similarly between T_2 and T_3); the other lead assures electrostatic excitation of group No. 2 (and No. 3) at line voltage; the tap switch of T_2 (and T_3) is set on the zero tap. Transformer T_2 is also excited magnetically for voltages between

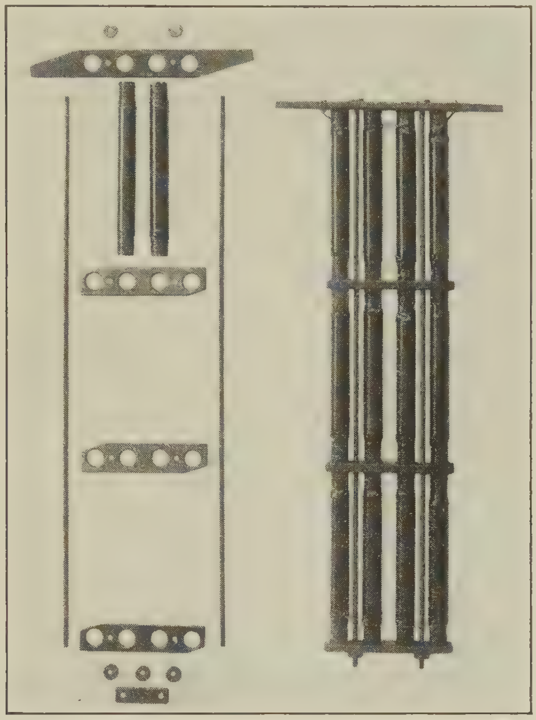


FIG. 4—PARTS AND ASSEMBLY OF A 10,000-OHM RESISTOR SECTION

(Approximately 36 in. x 8 in): 833-ohm resistor tubes; insulating spacers, binders, and tie rods

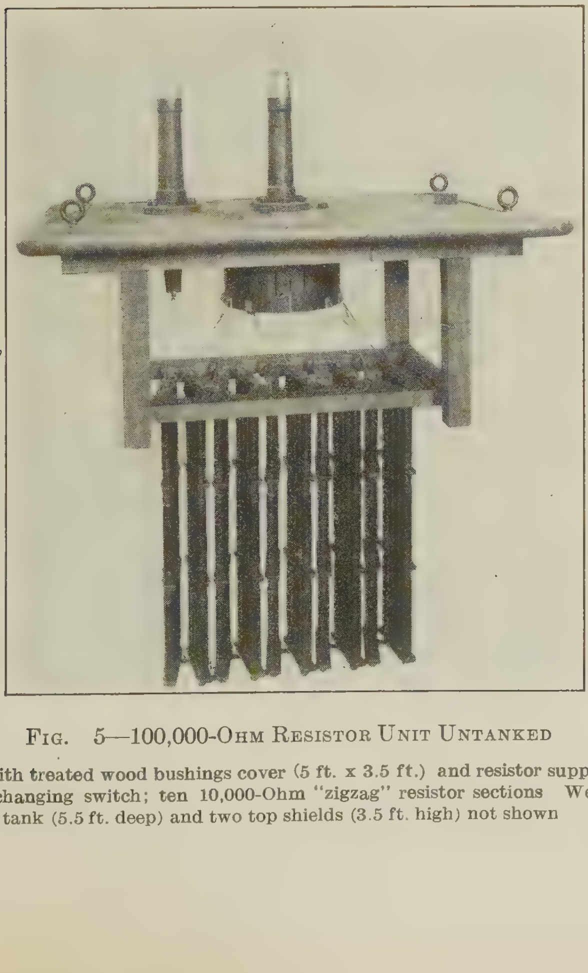


FIG. 5—100,000-OHM RESISTOR UNIT UNTANKED

With treated wood bushings cover (5 ft. x 3.5 ft.) and resistor supports; tap-changing switch; ten 10,000-Ohm "zigzag" resistor sections Welded steel tank (5.5 ft. deep) and two top shields (3.5 ft. high) not shown

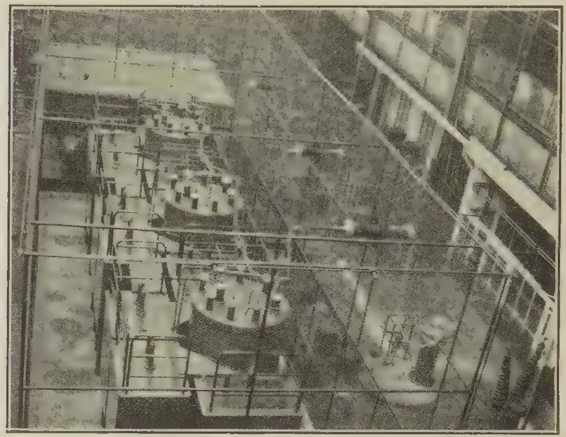


FIG. 6—132-KV. SHIELDED POTENTIOMETER: THREE 44-KV. GROUPS, GROUP AREA AND SCREEN; OPERATING BOOTH; TESTING AREA

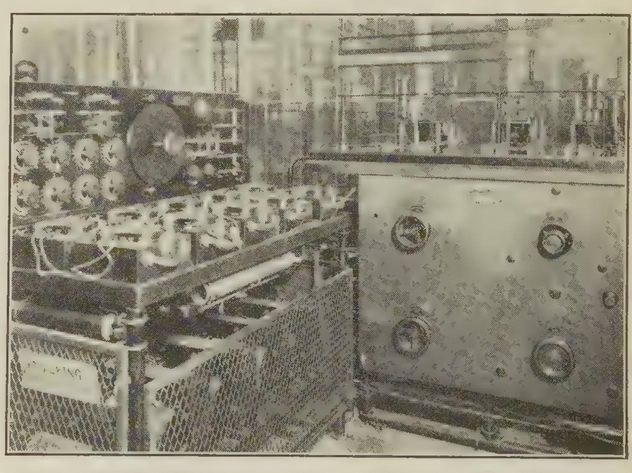


FIG. 7—INTERIOR OF OPERATING BOOTH: OPERATING PANEL, INSTRUMENTS, AND BURDENS; PIER FOR REFLECTING DYNAMOMETERS; FIELD CONTROL PANEL

44 and 88 kv. and transformer T_3 for voltages between 88 and 132 kv.; the "highest" transformer tap used in either Group No. 2 or Group No. 3 has in general the same nominal voltage rating as the corresponding tap (100 per cent or 50 per cent only) of the "highest" resistor unit in use. The correctness of the shielding transformer tap setting is checked in all cases by comparing the reading of a 600-volt voltmeter, Vm, supplied from the secondary of T_1 with the reading of a 150-volt voltmeter supplied from the secondary of the potential transformer under test; the proper ratio between the two readings is predetermined for each marked or nominal potential transformer ratio. The connections for 66 kv. are indicated in Fig. 3A and B.

The distribution of voltage in the resistor units and in the shielding transformers for the 132-kv. connection is summarized in Table II. In this case the indicated current in the resistor circuit would be approximately 0.11 ampere, while the ratio between the secondary voltages of T_1 and of a 132-kv.:110-volt (1200:1 ratio) potential transformer under test would be approximately 440:110 or 4:1.

TABLE II
DISTRIBUTION OF VOLTAGE AT 132 KV. IN THE THREE 44-KV. GROUPS

Designation			Shielding Transformer Tap		
Group No.	Resis. Unit	Shield Trans.	No.	Kv.	Connected to
			0	0	Ground
			1	5.5	Tank of 1st Unit (A_1)
	A_1		2	11 *	—
			3	16.5	Tank of 2nd Unit (B_1)
1	B_1	T_1	4	22 *	—
			5	27.5	Tank of 3rd Unit (C_1)
	C_1		6	33 *	—
			7	38.5	Tank of 4th Unit (D_1)
	D_1		8	44 *	Tap No. 0 of T_2
			0	44	Tap No. 8 of T_1
			1	49.5	Tank of 5th Unit (A_2)
	A_2		2	55 *	—
			3	60.5	Tank of 6th Unit (B_2)
2	B_2	T_2	4	66 *	—
			5	71.5	Tank of 7th Unit (C_2)
	C_2		6	77 *	—
			7	82.5	Tank of 8th Unit (D_2)
	D_2		8	88 *	Tap No. 0 of T_3
			0	88	Tap No. 8 of T_2
			1	93.5	Tank of 9th Unit (A_3)
	A_3		2	99 *	—
			3	104.5	Tank of 10th Unit (B_3)
3	B_3	T_3	4	110 *	—
			5	115.5	Tank of 11th Unit (C_3)
	C_3		6	121 *	—
			7	126.5	Tank of 12th Unit (D_3)
	D_3		8	132 *	Line

*Voltage at corresponding resistor unit; the resistor and transformer circuits are joined at "Ground" and "Line" only.

After obtaining the proper settings as outlined, the desired secondary burden is set by means of dial switches and verified by instrument readings. The ratio and phase-angle readings are then taken as indicated under "Principles of Operation."

Detailed Description

The principal items described in the complete paper are: (1) 100,000-ohm resistor units, (2) fractional and accessory resistors, (3) operating panel and burdens, (4) shielding transformers, and (5) connections; a partial list of auxiliary equipment is included under (6).

Preliminary Work

An accuracy guarantee of within 0.1 per cent in ratio and within 5 minutes in phase angle means that the accuracy obtainable with the equipment under actual test conditions must be well within those limits in order to provide a reasonable "margin of safety" in the guarantee to cover slight differences between test and operating conditions. This in turn means that the sources of error in the equipment must be thoroughly investigated and that errors of the order of 0.01 per cent and 0.5′ are important.

An absolute accuracy better than within about 0.01 per cent cannot be expected for d-c. resistance values obtained by the best methods available; this limit must be somewhat increased for direct measurements with a high grade Wheatstone bridge. However, a much greater degree of comparative accuracy can be obtained by measuring the difference between two nearly equal resistors or between two nearly equal conditions of the same resistor. Therefore the latter method, which is also applicable to a-c. measurements, was used whenever possible in investigating the sources of error.

The following investigations or tests on the completed equipment, preliminary to using it for routine testing, are outlined in the complete paper: leakage, heating and capacitance of unit; characteristics of shielding transformers; effect of incorrect tank potentials, and of corona and capacitance on operation (special conditions); determination of phase-angle corrections.

Test Results

Representative ratio and phase angle results obtained to date with the new potentiometer are not included as it is not the purpose of the paper to discuss the characteristics of potential transformers. It will be evident, also, that a tabulation of test results, although undoubtedly of interest in that connection, is not necessary to demonstrate the soundness of the general proposition that all potential transformers should be tested for accuracy at full rated voltage; this procedure is now possible up to 150 kv. maximum at from 25 to 60 cycles.

Acknowledgment

The development, design, construction, and testing of a previously untried combination of equipment of such magnitude, to operate under conditions for which few useful data were available, would have been impossible without the cooperation and the suggestions of a large number of individuals.[4] Their assistance is greatly appreciated and the author regrets that a more direct acknowledgment is not possible here. It is a pleasure, however, to acknowledge particularly the assistance of Mr. C. W. LaPierre.

4. Principally in the General Engineering Laboratory at Schenectady, in the Pittsfield Works Laboratory, and the General Transformer Engineering Department at Pittsfield.

ILLUMINATION ITEMS

Submitted by
The Committee on Production and Application of Light

THE CENTER FIXTURE IN RESIDENCE LIGHTING

By Helen G. McKinlay*

To prescribe as a doctor may for the cure of an evil, with a reasonable assurance that at least the medicine will be given a trial, would be delightful to those planning the lighting for the homes of today.

Unfortunately, however, many people revolt against the cures recommended to overcome their lighting evils. Indisputably light from a center ceiling fixture will provide one of the most effective cures for inefficient "general" lighting in a room. Also, invariably when such suggestion is made the reaction against it, particularly by women, is "I don't like a center fixture." She doesn't say, "I don't like light in the center of a room," although many of us are apt to misinterpret her remark to mean that. What she really dislikes *is* the fixture! What price lighting!!

Many of us concede that overhead lighting brings about the best results in illumination and in lighting results, yet recognize that the medium through which it is achieved has indeed room for improvement.

The woman usually thinks of the lighting of her home in terms of the appearance of the fixture; she uses this as her standard simply because she hasn't given any thought to lighting as a science, nor considered its results if correctly applied. And as a consequence, when ceiling fixtures are suggested, she pictures that unattractive fixture,—an atrocity contemporaneous with the building of the last home in which she lived in which there was a ceiling fixture, and even some of the newer ones which are not departures from their antecedents.

With a better understanding of lighted effect, women will want center lighting on merit, but never will they accept it so long as it must be had at a sacrifice in the appearance of the room, nor until more pleasing fixtures are to be had.

Happily not all center fixtures are unattractive. And thanks to those manufacturers who have made good looking ones it is not a difficult problem to "sell" women on center lighting. They are quick to recognize the merit of central light from overhead when light is desired throughout the entire room, if it may be acquired through an unobstrusive fixture; they are rather intrigued with the fact too that by use of a center fixture instead of wall brackets, and plenty of outlets to connect their table and floor lamps, they may provide without sacrifice of light for their over-indulged "indoor sport" of rearranging the furniture in their rooms.

Homelighting must be sold to women. And women think of homelighting largely in terms of table and floor lamps. Fixtures mean little more to the average woman than the radiators or other permanent impersonal household accessories. But if fixtures are made more pleasing to the woman's eye in appearance, and of course supervised by an engineer's eye for proper construction in design, a firmer foundation upon which to build better homelighting will be established and more readily accepted.

*Edison Lamp Works of General Electric Company, Harrison, N. J.

TRAFFIC CONTROL

By W. T. Dempsey*

The new Code for Standardization of Street Traffic Signs, Signals and Markings built up by a Sectional Committee wherein the American Institute of Electrical Engineers was represented has now been completed. It has been accepted by the American Engineering Council which participated during the past several years in the national conferences on street and highway safety inaugurated by Herbert Hoover when Secretary of Commerce. He cystallized consideration of the subject in a national conference on street and highway safety, in an effort to minimize the possibility of accidents and reduce the numerous loss of life and injuries resulting from accidents on the public streets and highways throughout the country. Surveys were made in 35 states and returns analyzed were collected in more than 100 cities and it is believed that the returns covering all conditions and methods of traffic control and regulation will show that this survey has been of great benefit. The final report of the Committee is now in circulation throughout the country by the American Engineering Council and efforts are being made to have the Standard Code inaugurated into laws in every state in the Union to standardize devices of every description for the regulation of traffic and safety on the public highways.

Definite recommendations have been made to the effect that roadway signs installed for the safety of night driving, including important directional signs, be adequately illuminated. In fact the proper illumination of precautionary road signs is placed first in order of importance for safety on the highways for night driving. They should be visible for a distance of 100 ft.

Considerable space is devoted in the report to a consideration of the types of street traffic control signals which, of course, are generally operated by means of electrical devices, relays, various types of lenses and control circuits. As a general thing such regulating signals are controlled by means of synchronous motors. However, the system of remote control using pilot wires permits a very flexible form of operation. Normally the control of traffic of an entire City is operated from one central point. Under extraordinary traffic conditions at a particular place on a certain thoroughfare this system permits the control to be sectionallized as may be necessary to handle that particular part of the thoroughfare independently of the traffic regulating devices in other areas.

*Supt. Service Maintenance & City Lighting Service, New York Edison Company.

Another very commendable and noteworthy economy in the regulation of traffic by means of several types of electrically operated devices now on the market, is the releasing of police officers from this form of duty and permitting them to devote their time to real police work. These systems of control also eliminate the officer from the hazardous condition of directing traffic in the center of congested roadways, a step in the interests of safety.

ADVANCES IN INDUSTRIAL LIGHTING PRACTISE

By A. D. Bell*

The better types of industrial lighting installations today are characterized especially by two things; much higher levels of intensity, and reflecting equipment better suited to individual lighting problems so that glare is practically eliminated.

Higher levels of artificial illumination have gradually come into greater use largely on account of a realization on the part of the industrial plants of the several advantages to be gained through such illumination. The activities, first of lamp and reflector manufacturers and then, more recently, those of central stations, are convincing the industrial owners or managers of the value of proper artificial illumination by means of actual demonstrations and tests. Increasing efficiencies of light production and economic considerations, such as a lowering of electrical current rates and cheaper incandescent electric lamps, have likewise played a large part in this movement. Electric light is now so cheap that it can be used freely to attain the manifold benefits that it alone can produce.

Today we find foot-candle levels of 20, 40, 50 and higher, yet a decade ago 5 foot-candles was considered excellent for artificial lighting. Present levels when compared with those of natural sunlight (running into the thousands of foot-candles) are indeed puny, but if we look on the other hand at the general level of but a few years ago we can see that we are making real progress. However, we seem to be as far now from the saturation point in lighting as we were ten years ago because our objective is ever advancing.

In the field of industrial lighting equipment the changes have been many and varied. Types and varieties intended for the earlier types of incandescent lamps became obsolete with the advent of the present day lamps which have a different light distribution, different physical dimensions and a much higher brightness. This required new designs on the part of reflector manufacturers and as a result today we have a variety of reflectors made of different materials and suited to different conditions of use. In industrial service those made of enameled steel seem to predominate, largely on account of their efficiency, durability and ease of cleaning, with glass reflectors coming next in order. The glass equipment in both the prismatic and mirrored types find considerable application and are, too, very satisfactory. Other metal reflectors are also made, those in aluminum finish probably being the outstanding ones. Tin reflectors, coated with paint, are still used but there has been a decided trend toward the use of the better equipment which, though initially more costly, lasts much longer and is more satisfactory in the long run.

Of the more recent reflector developments we find several which might well be mentioned. In the vapor-proof class, reflectors have been brought out which fill a long standing need as they are not only truly vapor-proof but will actually stand up under acid fumes as well. For light directing and distributing qualities they are similar to the ordinary varieties.

To keep up with the trend toward higher intensities of illumination there are now available reflectors which will take the larger sizes of incandescent lamps. The Glassteel Diffuser is made in the 750- and 1000-watt size and both prismatic and mirrored glass reflectors for high mounting are obtainable in the 1000- and 1500-watt sizes. It is, of course, extremely important that glare be avoided and the new reflectors have been designed with this in mind.

For high intensities of illumination on small areas, and for the lighting of surfaces such as those of automobile bodies in the process of being finished, there have been put on the market concentrating types of reflectors which are particularly well adapted to this sort of work.

So much depends upon artificial illumination today in practically all our industrial enterprises that when we find marked improvements and developments in equipment it is an encouraging sign and indicates that the reflecting equipment is keeping pace with the demands of industry. When we note, too, that continuously higher levels of illumination are being successfully applied we can readily conclude that this field of electrical application is at last receiving due attention and that it holds almost unlimited possibilities for future growth.

*Edison Lamp Works of General Electric Company, Harrison, N. J.

PURCHASED POWER FOR RAILWAYS

In a recent address before the Boston Chamber of Commerce, President Atterbury, of the Pennsylvania Railroad strongly indorsed the purchase of electrical power for the use of electrified railroads rather than entering the power business for supplying their own properties. Speaking of the magnitude of the work of changing the motive power of the railroad, he said:

"We worked out a jointly owned power-plant scheme with the United Gas Improvement Company and the Philadelphia Electric Company but decided not to go into it. Why should we enter the power business? We have no warrant to go into that business which is an industry by itself. By the time we are ready to use it we shall be buying power cheaper than we can make it ourselves and thereby saving a capital investment of from $20,000,000 to $30,000,000 over a great number of years."

Institute and Related Activities

The Dallas Regional Meeting

Engineering topics of live interest are on the program of the Regional Meeting of the South West District of the Institute in Dallas, Texas, May 7-9. Headquarters will be in the Adolphus Hotel. Four technical sessions are planned and there will also be two student sessions. Inspection trips, a most interesting lecture, a dinner-dance, etc., are other attractive events on the program.

Engineering Papers

A-c. networks, bare-wire distribution, interconnection, lightning research, and effect of lightning on transformers, reclosing high-voltage circuits, remote metering, oil pipe line electrification, electrical features of waterworks and lighting of flying fields and airways, are among the subjects which will be covered in the papers to be presented.

Student Meetings

Two student sessions will be held on the afternoon of May 7 and the morning of May 8, respectively. Student activities will be discussed and ten papers will be presented by students. A prize cup will be awarded for the best paper. All members are invited to attend these student sessions.

The Skyline of Industrial Dallas

Inspection Trips

A number of trips have been arranged to points of interest in and near Dallas. These are scheduled for 2:00 p. m., May 8, and the points which may be visited are as follows:

(a) Dallas Power & Light Company generating station

(b) Southwestern Bell Telephone Company dial and toll equipment

(c) Dallas Power & Light Company underground distribution system

(d) Other places, such as—refineries, cement plant, textile mill, stocking factory, cotton-oil mill, Trinity River Reclamation Project, Trinidad Electric Generating Station using powdered lignite, Western Union Plant, packing house, Proctor & Gamble Plant, flour mill, structural steel fabricating plant, and many other points of interest, can be inspected on request.

Lectures with Demonstrations

A most unusual and attractive lecture, supplemented by novel demonstrations will be given on the evening of May 7 by S. P. Grace of the Bell Telephone Laboratories, Inc. The title of this talk will be *Science and Research in Telephone Development.* Ladies, as well as men, will find this very enjoyable.

Entertainment

A dinner-dance on the evening of May 9, and provisions for playing golf are the chief entertainment features.

For the ladies, in addition to the entertainment already mentioned, there will be luncheons, drives, bridge, shopping tours, etc.

Reduced Railroad Rates

Reduced fares on the certificate plan have been arranged with the Southwestern Passenger Association. The special rate applies in full to all who purchase tickets in the Southwestern territory. Those who attend from the East may also benefit by the rate if they buy straight tickets to any point in the State of Arkansas, Kansas, Missouri, Oklahoma and Texas, and Memphis, Tennessee, and then re-buy from this point to Dallas.

Under this plan a certificate should be obtained when the ticket to Dallas is purchased. This certificate should be deposited at the registration desk at the meeting and if 100 certificates are deposited, return tickets may be purchased at one-half the regular fare. The same route must be followed in returning as used in going to Cincinnati.

Tickets will be sold from May 3 to May 9 and the latest return date is May 13.

Everyone should get a certificate whether he will use it or not. Doing this will help others to take advantage of the reduced fare which may result in considerable saving to those coming long distances.

Register in Advance

By registering in advance by mail, members will help the local committees in making plans.

At the meeting a registration fee of one dollar will be charged. Students and ladies will be exempt from this fee.

Hotel Reservations

Hotel reservations should be made by communicating directly with the management of the hotel. Rates for the headquarters hotel, the Adolphus, and for other nearby hotels are given below. A special rate for students of 75c. per day has been made by the management of the Adolphus Hotel.

HOTEL ROOM RATES

Name	Without bath		With bath	
	Single	Double	Single	Double
Adolphus			$2.00–6.00	$3.50–8.00
Baker			2.00–5.00	4.00–7.00
Jefferson	$2.00	$3.00	3.00	5.00
Hilton	1.50–1.75	2.75	2.00–3.00	3.50–6.00
Scott			2.00–2.50	4.00–5.00
Sanger Apts			2.00–2.50	5.00
Mayfair			2.00–2.50	4.00–5.00

Committees

The Regional Meeting Committee of the Southwest District is as follows: B. D. Hull, Chairman, Vice-President South West

District; A. E. Allen, Secretary; L. T. Blaisdell, C. V. Bullen, B. J. George, W. C. Looney, G. A. Mills, C. P. Potter, G. C. Shaad, and J. B. Thomas.

The officers of the other committees are: *Local Committee*—G. A. Mills, Chairman; A. Chetham-Strode, Secretary; *Meetings and Papers*—J. B. Thomas, Chairman; *Entertainment & Reception*—L. T. Blaisdell, Chairman; *Transportation & Inspection*—W. C. Looney, Chairman; *Hotels & Registration*—E. L. Glander, Chairman; *Attendance & Publicity*—T. C. Ruhling, Chairman; *Finance Committee*—C. G. Matthews, Chairman; *Student Activities*—G. C. Shaad, Chairman.

Papers by Student Members

Evaluation of Physical Property of Distribution Systems, T. E. Peters, University of Arkansas.

Piezoelectric Oscillators, Leroy Moffett, Jr., University of Oklahoma.

Frequency Stability of Split-Anode Magnetron Oscillators, Norvel Douglas, University of Kansas.

A General Network Theorem, L. R. Brown, University of Texas.

The Effect of Terminating Impedances on the Characteristics of Filters, M. J. Miller, Washington University.

8:00 p. m. Address "Science and Research in Telephone Development," S. P. Grace, Bell Telephone Laboratories, Inc.

WEDNESDAY, MAY 8

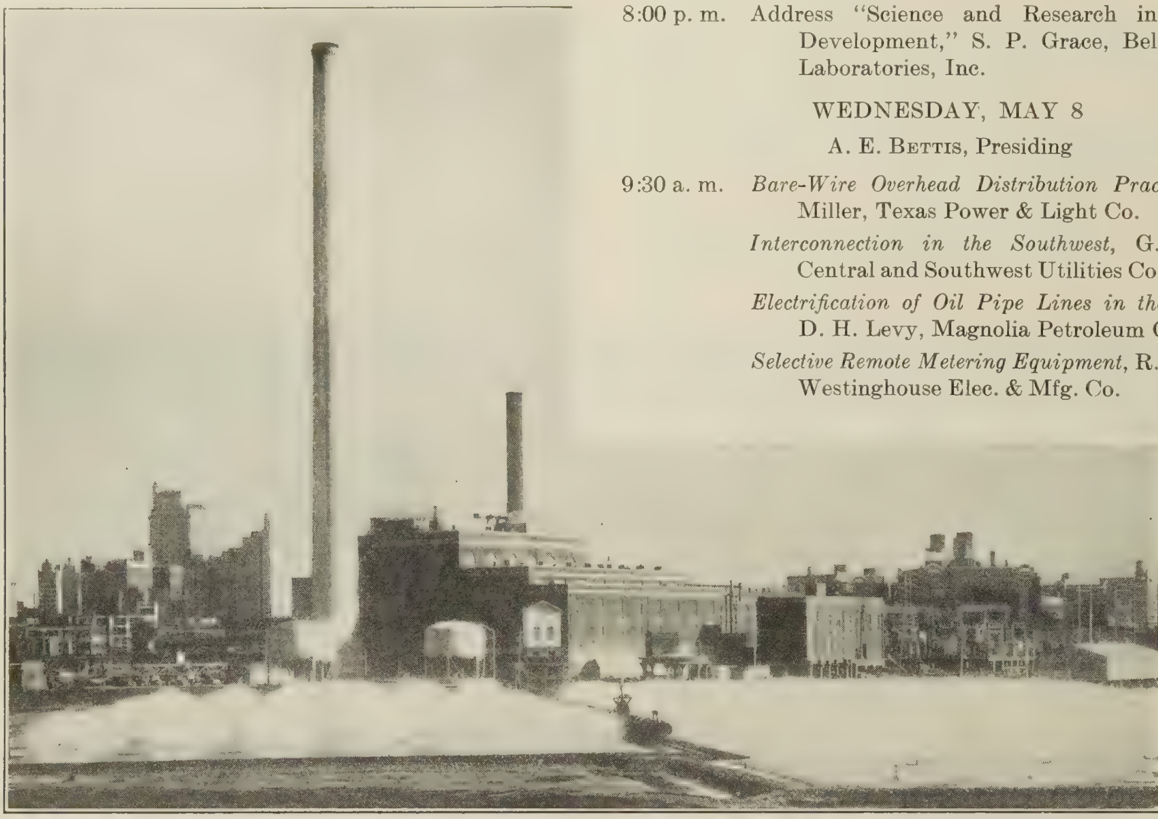
A. E. Bettis, Presiding

9:30 a. m. *Bare-Wire Overhead Distribution Practise*, M. C. Miller, Texas Power & Light Co.

Interconnection in the Southwest, G. A. Mills, Central and Southwest Utilities Co.

Electrification of Oil Pipe Lines in the Southwest, D. H. Levy, Magnolia Petroleum Company.

Selective Remote Metering Equipment, R. J. Wensley, Westinghouse Elec. & Mfg. Co.



Generating Plant of the Dallas Power and Light Company

PROGRAM OF DALLAS REGIONAL MEETING

TUESDAY, MAY 7

9:00 a. m. Registration.

10:00 a. m. Opening of Convention. B. D. Hull, Vice-President, 7th Geographical District, A. I. E. E. presiding.

Address of Welcome.

Power Session

G. A. Mills, presiding

Developments in Network Systems and Equipment, T. J. Brosman and Ralph Kelly, Westinghouse Elec. & Mfg. Co.

Standard Voltage A-C. Network, John Oram, Dallas Power & Light Co. .

Automatic Reclosing of High-Voltage Circuits, E. W. Robinson and S. J. Spurgeon, Alabama Power Co.

12:30 p. m. Joint Luncheon with Dallas Electric Club.

2:00 p. m. Joint Meeting Student Branches and Sections. G. C. Shaad, Chairman.

Remarks, R. F. Schuchardt, President, A. I. E. E.

Student Session

9:30 a. m. Opening Remarks, B. D. Hull, Vice-President, 7th Geographical District, A. I. E. E.

Student Activities. H. H. Henline, Assistant National Secretary, A. I. E. E.

General Discussion.

Papers by Students

A Method of Measuring Surface Iron Losses, H. E. Gove and R. A. Folt, University of Missouri.

Positive Sense: Its Appliaction to Vector Diagrams T. W. Beams, Texas A. & M. College.

Performance of Standard Transformers Connected as Auto-Transformers, J. J. Loving and G. R. G. R. Redden, Texas A. & M. College.

Supervision of Gas, Electric and Water Meters in Texas, W. E. Henrichson, University of Texas.

A Universal Deficiency Compensating Amplifier, J. E. Peek, Oklahoma A. & M. College.

2:00 p. m. Inspection Trips.

7:00 p. m. Dinner-Dance.

THURSDAY, MAY 9

Morning Session

J. B. Thomas, Presiding

9:30 a. m. *Progress in Lightning Research*, F. W. Peek, Jr., General Electric Co.

Lightning Studies of Transformers by the Cathode Ray Oscillograph, F. F. Brand and K. K. Palueff, General Electric Co.

Flying-Field and Airway Lighting, R. Odgen, U. S. Army.

Electrical Features of the New Kansas City Water Works Plant, A. L. Maillard, Consulting Engineer.

A View of One of the Sixteen Golf Courses in Dallas

Afternoon Session

W. O. Pennell, Presiding

2:00 p. m. *Meeting Long-Distance Telephone Problems in the Southwest*, H. R. Fritz and H. P. Lawther, Southwestern Bell Telephone Co.

Railway Train Signal Practise, P. M. Gault, Missouri-Pacific System.

Telephone Transmission Networks, T. E. Shea and C. E. Lane, Bell Telephone Laboratories.

Program Transmission over Telephone Circuits for National Broadcasting, F. A. Cowan, American Telephone and Telegraph Co.

The 1929 Summer Convention

A Summer Convention which promises to equal any past Institute convention in excellence of technical discussion and in pleasurable entertainment is being planned for this year's meeting at Swampscott, Mass., June 24 to 28. The New Ocean House will be headquarters for the meeting. During the past six years, the progress of the electrical development in New England has made remarkable strides; the electrification of industry has created a multiplicity of opportunities for the study of advanced and diversified practise in the application of motors and control, modern lighting facilities, and industrial heating. Interconnection of tidewater steam plants and interior hydro plants by transmission lines has established a network of power supply; a pioneer rotary condenser operating in an atmosphere of hydrogen is in service in Pawtucket; the radio broadcasting stations, universities, colleges, and communication companies are preparing for engineering and historic trips which this richly developed region affords. In the technical program planned by the Convention Committee such subjects as distribution, electric transportation, electrical machinery, shielding in electrical measurements and others of these topics will be presented.

Reviews of developments in all phases of electricity will be covered in the annual reports of the Institute Technical Committees. Several worth while inspection trips as well as sight seeing trips are being arranged.

Annual conferences of Officers, Section Delegates, and Branch Delegates will be another important part of the meeting to which the first day will be devoted.

Plans for entertainment and recreation are being formulated by a large and enthusiastic convention committee. These will include tournaments for golf and tennis, a dinner, a reception, dancing, and a day's trip to York Beach.

Further details of the Convention will be published in succeeding issues of the Journal.

Radio Engineers to Meet April 3

The New York Meeting of the Institute of Radio Engineers to be held on the third of April in the Engineering Societies Building will have on its program the following interesting and instructive papers:

Broadcast Stations, by Henry L. Bogardus and Charles T. Manning (to be presented by Mr. Bogardus); The Testing of Piezo Oscillators for Broadcasting Stations, by E. L. Hall; Observations on Modes of Vibration and Temperature Coefficients of Quartz Plates, by F. R. Lack; A High Precision Standard of Frequency, by W. A. Marrison; A Convenient Method for Referring Secondary Frequency Standards to a Standard Time Interval, by L. M. Hull and James K. Clapp (to be presented by Mr. Clapp); Frequency Measurement, by S. Jimbo (to be presented by Doctor Walter G. Cady); and The Precision Measurement of Time, by Alfred L. Loomis.

The American Welding Society Annual Meeting

With the opening session April 24, and continuing with other technical sessions through the morning of the 26th of the month, the program of the American Welding Society's Annual Meeting to be held in the Engineering Societies Building, will include interesting papers on the various applications and phases of welding, closing with a review of progress made to date and a discussion of future committee activities.

Colloquium on Power-Circuit Analysis at M. I. T.

From June 10 to June 22 inclusive, there will be conducted at the Massachusetts Institute of Technology by its Electrical Engineering Department aided by power transmission engineers and operators from various sections of the country, a Colloquium on Power-Circuit Analysis with special reference to the behavior of machinery and transmission line stability. Registration on June 10 will be at 10:00 a. m., with technical session in the afternoon under the auspices of the Electrical Engineering Staff of M. I. T.; Tuesday's sessions will be led by the General Electric Company and the Westinghouse Electric & Mfg. Co., the technical session on Wednesday, the 12th, by an eastern or midwestern company, and on the following day there will be another technical session followed by a general discussion of points raised at the four preceding sessions. Each day's technical program takes up some subject of interest and importance to the profession. On Wednesday, June 19th, there will be a demonstration of the integraph and the calculating table in the Electrical Research Laboratories of the institute. A final announcement, giving other details and the names of the various speakers, will be sent out in May. Inquiries may be addressed to Professor G. C. Dahl, who is director of the Colloquium.

Twelfth Exposition of Chemical Industries

With the growing importance of modern chemical engineering to almost every field of industry, interest in the Twelfth Exposition of Chemical Industries to be held in Grand Central Palace the week of May 6th is bound to be general. One important feature will be Export Day, May 9th, when the exhibitors will be especially prepared to meet foreign guests and discuss with them their products and problems. Student courses are also being arranged under the direction of Professor W. T. Read, of Texas Technological College, who will place the attendant lectures with competent speakers.

A. I. E. E. STANDARDS

Test Codes for Electrical Machines

In the Journal for January the proposal to establish test codes for electrical apparatus was mentioned. A further step has now been taken in this connection as the Standards Committee of the Institute at its meeting of February 27th directed that a committee should be appointed to make a survey of the situation. This action was taken following a report from the Electrical Machinery Committee expressing an opinion that the development of such electrical test codes would be a very valuable and desirable activity of the Institute. Chairman Newbury of the Standards Committee has appointed the special committee with the following personnel: F. M. Farmer, chairman and W. J. Foster, A. M. MacCutcheon, W. I. Slichter and E. C. Stone. This committee will report on the desirability, scope, general methods of work, probable expense and time involved in preparation of such codes.

In a general way what is meant by a test code for electrical apparatus can be most easily determined by reference to the Test Codes developed by the American Society of Mechanical Engineers, such as steam boilers, reciprocating engines, pumps, condensing apparatus, etc. The purpose of electrical test codes would be to provide standard directions in detail for conducting and reporting acceptance and performance tests of electrical machinery and apparatus. It is realized by the Standards Committee that this proposed undertaking is a long and expensive one and comments on its value are being solicited from men throughout the electrical field. If those interested will send in their comments it will be greatly appreciated. Address H. E. Farrer, Secretary Standards Committee, A. I. E. E., 33 West 39th St., New York, N. Y.

Values of A-C. Test Voltage for Household Devices Cancelled

In the 1922 Edition of the A. I. E. E. Standards, Rule 16,000—"Values of A-C. Test Voltage for Household Devices"—specifies a test of 500 volts at operating temperature for heating devices taking not over 660 watts and intended solely for operation on supply currents not exceeding 275 volts. This rule has never been replaced in the work of revision and in accordance with Standards procedure is therefore still applicable. In the opinion of the Standards Committee, because of the low value of test specified, the rule should be cancelled. An action recommending such action to the Board of Directors was taken and will come before the Board at its meeting of March 21.

Standards for Heating Devices

Following the cancellation of Rule 16,000, mentioned previously, the Standards Committee directed that a committee be appointed to investigate the field of both household and industrial electrical heating devices. The committee will report whether the Institute should undertake to develop such standards.

Report on Graphical Symbols for Radio

Action was taken by the Standards Committee on February 27th recommending the publication as a Report on A. I. E. E. Standards of the report of the subcommittee of the Sectional Committee on Radio on "Graphical Symbols for Radio." This report is now in preparation and will be available shortly.

Bureau of Standards to Publish all Letter Symbols in Single Volume

In view of the usefulness of a single volume containing all the recently approved standards for letter symbols the Bureau of Standards on receipt of approval by the sponsors of the Sectional Committee on Scientific and Enginering Symbols and Abbreviations has agreed to publish such a volume. Individual pamphlets covering most of the symbols so far adopted can be purchased from Institute headquarters.

Engineering Fellowship at University of Wisconsin

The following fellowships in Engineering are available at the University of Wisconsin for the year 1929-30:

Three University Fellowships,—stipend $750 per year: available to graduates of engineering colleges of recognized standing, and intended to promote graduate study. Holders of these fellowships are expected to complete their work for the Master of Science degree in one year. A small amount of assigned work may be required.

Two Research Fellowships;—appointments for a period of two years, subject to satisfactory service; salary for the first year, $900; and for second year, $1100.—Appointees for these fellowships established to promote research work in the College of Engineering, are expected to devote not less than one-half their time to assigned research. There will be opportunity to complete the requirements for the Master of Science degree within the two-year period; under favorable conditions at the end of one year. Candidates must be graduates of Engineering Colleges of recognized standing, and preferably should have had one or two years of graduate study, teaching, or engineering experience. The period of service will be the usual academic year, including the short vacations.

Appointments to be made April 25; applications should be received not later than April 15.

Application blanks may be obtained from Dean F. E. Turneaure, College of Mechanics and Engineering, or Dean C. S. Slichter, Graduate School, University of Wisconsin, Madison, Wisconsin.

Winter Convention Discussion

A summarized report of the discussion of the technical papers presented at the Winter Convention, January 28 to February 1, is given in the following paragraphs. Complete reports of the discussion will be published in the TRANSACTIONS. In the following report the titles of the papers in each session are given immediately preceding the corresponding discussion.

SESSION ON DIELECTRICS AND ELECTROPHYSICS

Anomalous Conduction as a Cause of Dielectric Absorption, J. B. Whitehead and R. H. Marvin, Johns Hopkins University.

Power Factor and Dielectric Constant in Viscous Liquid Dielectrics, D. W. Kitchin, Simplex Wire & Cable Co.

Corona Ellipses, V. Karapetoff, Cornell University.

Flux Linkages and Electromagnetic Induction, L. V. Bewley, General Electric Company.

In the discussion E. R. Thomas suggested that Maxwell's theory of the equivalent circuit might be applicable to the common dielectrics, explaining his contention by test results on laboratory and commercial condensers. F. M. Clark said that he has concluded that high absorption and high dielectric loss in oils must be due in part at least to the presence of impurities. He agreed that the dipole theory of Debye gives as satisfactory explanation as any of dielectric action. G. M. J. Mackay suggested that in the determination of the relation between d-c. and a-c. effects it would be helpful to study geometrically simple set-ups and to exaggerate the effects found in commercial materials. He said that until measurements have been made on purified materials he hesitates to believe that the losses involved in molecular orientation are mainly responsible for the dielectric loss found in engineering practise. A. Nyman asked if experience has shown that absorption actually affects the life of a dielectric. J. B. Whitehead stated that he found nothing that indicates that dielectric loss at low frequencies can be explained by Debye's theory, though at high frequencies this theory explains the action as stated by Mr. Kitchin. Mr. Kitchin agreed that in liquid materials at low frequencies, such as 60 cycles, the dipole loss does account for the peak in the 60-cycle power factor curve. He disagreed with Mr. Clark's contention that impurities affected his results as he had used pure materials and checked the results in several ways.

SESSION ON CABLES

High-Tension Underground Cable Research and Development, G. B. Shanklin and G. M. Mackay, General Electric Company.

Some Problems in High-Voltage Cable Development, E. W. Davis and W. N. Eddy, Simplex Wire & Cable Co.

Ionization Studies in Paper-Insulated Cables—II, C. L. Dawes, H. H. Reichard and P. H. Humphries, Harvard Engineering School.

Reduction of Sheath Losses in Single-Conductor Cables, Herman Halperin and K. W. Miller, Commonwealth Edison Company.

Losses in Armored Single-Conductor Lead-Covered Cable, O. R. Schurig, H. P. Kuehni and F. H. Buller, General Electric Company.

M. T. Crawford in discussing the first paper pointed out that temperature changes have caused ordinary splicing sleeves to burst in cases where the cable insulation was loosely wrapped. He recommended that either splicing sleeves be made stronger or expansion chambers be provided. F. A. Brownell pointed out the improved performance which modern cables give. The maximum life obtained on five samples tested five years ago was 23 hr. at 192 volts per mil and 5 hr. at 224 volts per mil. At present, tests give 226 hr. at 202 volts per mil without failure and 95 hr. at 224 volts per mil. The tests leave the present cables free from wax and dendriditic designs except near the failure. Cables have been tested 25 hr. at 260 volts per mil with practically no temperature rise. In discussing oil-filled joints, Herman Halperin stated that his experience proved that oil does not migrate to any great distance from the joint. He disagreed with the recommendation to decrease temperature limits of present cables. T. F. Peterson stated that he believed that in cables for 600 to 1300 volts from 2 to 6 per cent of air is permissible.

In connection with the Dawes, Reichard, and Humphries paper, W. B. Kouwenhoven stated that the use of flat samples might have introduced errors as it is very difficult to prevent voids in such samples. He added that in his work a sealing compound of three parts beeswax and one part rosin had proved very satisfactory. J. B. Whitehead pointed out that with some kinds of paper at higher temperature the power factor decreases as the voltage is raised. In answer to Mr. Peterson's suggestion, Dr. Mackay admitted that gas may be present in cable without ionization if the pressure is high enough but stated that air is objectionable because it oxidizes the compound.

H. R. Searing stated that as triplex cables of the oil-filled type have been developed for operation at 66 kv. and below, he feels that these should be preferable to the single-conductor cable at these voltages on account of the poorer regulation resulting with the single-conductor cables. P. S. Creager mentioned some tests on single-conductor 26,000-volt cable, cross-bonded and grounded at every third length as in Fig. 2G of the Halperin and Miller paper. He found that under short-circuit conditions the voltage across the insulating joints was about 300. Mr. Miller stated that his company has not experienced difficulty with poor regulation or unbalanced loads among cables operating in parallel because the single-conductor lines are short and of equal length.

SESSION ON TRANSMISSION AND LIGHTNING

A Graphical Theory of Traveling Electric Waves between Parallel Conductors, V. Karapetoff, Cornell University.

Progress in Lightning Research in the Field and the Laboratory, F. W. Peek, Jr., General Electric Co.

1927 Lightning Experience on 132-Kv. Transmission Lines, Philip Sporn, American Gas & Electric Company.

Theoretical and Field Investigation of Lightning, C. L. Fortescue, A. L. Atherton and J. H. Cox, Westinghouse Electric & Manufacturing Company.

Protection of Transmission Lines from Interruption by Lightning, by 1927-28 Subcommittee of Power Transmission & Distribution Committee.

Following these papers, K. B. McEachron described tests he is making by applying artificial lightning surges to transmission lines. J. H. Cox said that he believed Mr. Peek claimed too strongly that lightning phenomena have been reduced to definite numerical values. J. J. Torok said he doubted Mr. Peek's contention that lightning energy can be dissipated within one span of a transmission line. C. F. Harding brought out the advantages of using a cathode ray oscillograph in lightning studies and briefly described a new instrument of this type developed at Purdue University. E. S. Lee described a cathode ray oscillograph of an actual lightning surge which was shown to be positive in polarity, unidirectional, reaching its maximum in 5 microseconds, decreasing to half value in 20 microseconds and to zero in 50 microseconds. Superimposed at the peak was a highly damped oscillation of 2,000,000 cycles. P. H. Thomas voiced the opinion that the rising front of the surge wave is the part due to lightning and that the length of tail depends altogether on the amount of line affected and its facility for dissipation. He suggested further that the resistance of tower footings is not important in the dissipation of surges as the reactance of lines and ground greatly predominates. Edward Beck pointed out that the cathode-ray oscillograph has shown that lightning surges do not have as steep fronts as formerly

thought and that a front of ¼ microsecond would be unusually steep. J. S. Mahan and M. G. Lloyd presented records of 248 companies showing the distribution of surge damages among different classes of station and line equipment.

Discussing Mr. Anderson's paper, F. C. Hanker pointed out the difference in purposes for which a-c. and d-c. circuit breakers are used. He questioned the widespread use of high-speed breakers in d-c. railway feeders. In answer to this, Mr. Anderson stated that for 1500-volt and 3000-volt d-c. feeders the high-speed breaker has distinct advantage and is practically a necessity.

In discussing the last three papers, P. H. Chase stated that the deion circuit breaker promises revolutionary advantageous changes in station design which will result from absence of oil and high speed of operation. S. M. Dean, Viele, R. C. Mason and C. A. Corney made similar comments. J. W. McNairy described briefly another type of airbreak breaker which he said utilizes a principle of deionization similar to that described in Mr. Slepian's paper. R. M. Spurck suggested the desirability of tests on the deion breaker in interrupting charging currents and exciting currents. In a written discussion, J. D. Hilliard claimed that neither oil throw nor an oil fire need accompany the interruption of an electric circuit by an oil circuit breaker. F. J. McKittrick asked if it is possible to have a circuit in which the voltage builds up faster than the rate of deionization. F. W. McNeill stated that the extension of the deion principle to 25,000-volt breakers bears considerable promise.

Answering Mr. Spurck's question, B. P. Baker stated that tests have indicated that the new breaker will open low currents quite satisfactorily. The time of interruption is longer on small currents but this time may be decreased by strengthening the blow-out field which, however, has not been thought necessary. In answering a question of Mr. Dean, he stated that use of a series disconnecting switch has been found unnecessary as safety requirements are met more economically by adding insulation to the breaker.

Session on Communication

Application of Radio in Aviation, J. H. Dellinger of U. S. Bureau of Standards.

Influence of Moisture and Electrolytes upon Textiles as Insulators, R. R. Williams and E. J. Murphy, Bell Telephone Laboratories.

Purified Textile Insulation for Telephone Central Office Wiring, H. H. Glenn and E. B. Wood, Bell Telephone Laboratories.

Vector Representation of Wave Filters, R. F. Mallina and O. Knacknuss, Victor Talking Machine Co.

William Fondiller in discussing the first two papers pointed out that formerly efforts had been made to increase the insulating strength of textiles by treatment with moisture-resisting compounds but that these treatments affected but slight improvement. The excellent results obtained by washing were due, he said, to applying the research point of view to the problem. E. B. Wood said the purified textile insulation might be valuable for use in tropical countries.

In answer to a question by H. W. Drake in connection with the paper by J. H. Dellinger, H. Diamond stated that it is sometimes difficult to get an airplane pilot to depend on indications of instruments rather than his visual observation.

Session on Induction Motors

The Condenser Motor, B. F. Bailey, University of Michigan.

The Fundamental Theory of the Capacitor Motor, H. C. Specht, Westinghouse Electric & Mfg. Co.

The Revolving-Field Theory of the Capacitor Motor, W. J. Morrill, General Electric Co.

Line-Start Induction Motors, C. J. Koch, General Electric Company.

Calculating No-Load Core Losses in Induction Motors, Thomas Spooner and C. W. Kincaid, Westinghouse Electric & Mfg. Company.

In discussing the first three papers, C. R. Boothby pointed out that the maximum torque of a capacitor motor is inversely proportional to the total resistance of the capacitor phase circuit. H. C. Louis asked if it is an inherent fault that the capacitor motor requires 30 to 50 per cent more starting circuit than repulsion motors. He asked also if condensers are made which will last in service. Answering this question A. Nyman stated that if large enough paper condensers are used, they will last for years. W. I. Schlicter said that reliable condensers are now being manufactured. In a written discussion, E. G. Michelsen and L. F. Hemphill stated that the capacitor motor is not inherently reversible but that its characteristics in this regard are dependent on the design, the value of external reactance being the predominating factor. H. C. Specht pointed out that claims should not be made that the capacitor motor is preferable where polyphase energy is available. P. H. Rutherford stated that he believed that when large production is obtained the cost of the capacitor motor will be very near that of the repulsion induction motor. W. J. Morrill said he thought the cost will be about 25 or 30 per cent higher for the capacitor motor than for another motor in the same competitive class.

Several of the speakers expressed the opinion that the present permissible starting currents allowed by the power companies are too low and A. M. MacCutcheon advanced the idea that possibly the time and the frequency of starting should be considered. F. E. Harrell commenting on Mr. Koch's paper claimed that it is questionable from the standpoint of manufacturing economy, that the double-cage motor is superior to the single-cage motor. C. W. Franklin pointed out that the power companies must require that starting does not give trouble to other customers, particularly on combined power and light circuits. For this reason he said incremental starting is desirable in some cases.

Session on Electrical Machinery

Insulations Tests of Electrical Machinery Before and After Being Placed in Service, C. M. Gilt, Brooklyn Edison Company, and B. L. Barns, Canadian General Electric Company.

Influence of Temperature on Large Commutator Operation, F. T Hague and G. W. Penney, Westinghouse Electric & Mfg. Company.

Effect of Transient Voltages on Power-Transformer Design, K. K. Palueff, General Electric Co.

Transient Analysis of A-C. Machines, Yu. H. Ku, Massachusetts Institute of Technology.

Two-Reaction Theory of Synchronous Machines—Part I, R. H. Park, General Electric Company.

J. S. Henderson in connection with the first paper claimed that if turbine generators must be dried out after installation space heaters should be used instead of short-circuit current in the generator windings. He also suggested tests shorter than one minute on installed apparatus. F. E. H. Mowbray disagreed with the maintenance tests proposed by the Gilt and Barns paper. He recommended a test to ground on one phase at a time with the other phases grounded, at 130 per cent of normal line voltage for 15 seconds. D. A. McKenzie advocated rigid adherence to A. I. E. E. Standards in testing newly installed generators. F. D. Newburg said he doubted that standards could be agreed upon for tests during service. W. F. Dawson cautioned that dust and dirt should be removed from windings before they are subjected to high-voltage tests. Several speakers agreed that standardization of tests immediately after installation is desirable but that periodic service tests cannot be standardized.

In discussing the Hague and Penney paper, C. R. Soderberg emphasized the great value of the brush-drop test for analyzing the mechanical behavior of commutators. C. L. Dawes enumerated some of the qualities required in commutator mica and discussed the effects of varying the amount of binder. F. D.

Newbury stated that in connection with commutators the A. I. E. E. Standards need revision so that the requirements will be based on mechanical tests rather than electrical. G. W. Penney pointed out further that the allowable temperature also depends on the mechanical construction of each commutator.

J. F. Peters pointed out the difficulty of equalizing voltage stresses in transformers by means of static shields as suggested in the paper by K. K. Palueff. F. W. Peek, Jr. spoke of the advantages of making a transformer oscillation-proof as is attempted in M. Palueff's design. He explained also that it is impossible to protect a transformer by installing an inductance in series with it, as the resulting voltage on the transformer windings may actually be increased by this arrangement in case of an impulse voltage on the line. V. M. Montsinger stated that the A. I. E. E. Rules for transformers on solidly grounded systems are not satisfactory. These rules specify that insulation should be tested at 2.73 times normal line voltage. Experience has shown, he said, that this practise is satisfactory in sections where lightning is not severe but is not satisfactory in severe lightning sections.

Session on Electrical Measurement of Non-Electrical Quantities

Magnetic Analysis of Materials, R. L. Sanford, U. S. Bureau of Standards.

Measurements of Flow by Use of Electrical Instruments, W. H. Pratt, General Electric Company.

Use of the Oscillograph for Measuring Non-Electrical Quantities, D. F. Miner and W. B. Batten, Westinghouse Electric & Mfg. Company.

Study of Noises in Electrical Apparatus, Thomas Spooner and J. P. Foltz, Westinghouse Electric & Mfg. Company.

Electrical Aids to Navigation, R. H. Marriott, Consulting Engineer.

Commenting on Mr. Sanford's paper, B. M. Smith mentioned a further useful application of magnetic analysis; namely, the determination of the chemical composition of magnetic materials. A. V. de Forest stated that he believed magnetic tests are more fundamental than mechanical tests.

In connection with the paper by Messrs. Miner and Batten, M. A. Rusher mentioned several additional mechanical measurements which can be made by means of the oscillograph, such as displacement, rotational speed, vibration, timing, sound-recording, etc. A. V. de Forest stated that a carbon pile has been developed which is very useful in measuring pressures and movements in connection an oscillograph. W. B. Kouwenhoven told of several medical uses of electrical measurements. T. B. Floyd and Perry Borden both told of the use of one oscillograph element in measuring more than one quantity. Mr. Borden citing a case when time, rotational speed and current were recorded in one curve. C. A. Mead outlined the use of the oscillograph in piano tuning. F. G. Graph mentioned its use in determining the extent of oil pools. E. S. Lee described the use of electrical measurements in determing the shaft horsepower on very large electrically driven ships.

Session on Instruments and Measurements

Telemetering, C. H. Linder, H. B. Rex, C. E. Stewart and A. S. Fitzgerald, General Electric Co.

Totalizing of Electric System Loads, P. M. Lincoln, Cornell University.

A New High-Accuracy Current Transformer, M. S. Wilson, General Electric Company.

132-Kv. Shielded Potentiometer for Determining the Accuracy of Potential Transformers, C. T. Weller, General Electric Company.

A Precision Regulator for Alternating Voltage, H. M. Stoller and J. R. Power, Bell Telephone Laboratories.

In discussing the first paper, S. C. Jacobi described the telemetering system of the Montaup Electric Company and outlined several advantages of the system.

In connection with Dr. Lincoln's paper, H. B. Brooks pointed out that where graphic records are not required other types of instruments than the potentiometer are satisfactory for indicating the voltages produced by the thermal converters. F. L. Lawton, D. A. McKenzie and A. R. Welds stated that the scheme of totalizing has been used extensively on their company's system with advantageous results. Bela Gati suggested the use of of barretter wires (having very small diameter) in the totalizing meter. He said this would reduce the time of response to about 0.0001 second. In answer to a question, Dr. Lincoln stated that there is no error in indication when the meter is operated at half voltage and double current.

J. B. Gibbs and A. M. Wiggins in discussing Mr. Wilson's paper stated that smaller transformers with hypernik cores and without special compensation will give about the same performance as the silicon steel transformers with the compensation described in the paper.

In discussing the paper by C. T. Weller, W. B. Kouwenhoven described a voltage divider which he had made in which the resistance was furnished by a tube of "manganin solution." This solution he said has a constant resistance and a tube one meter long and 1.08 mm. in diameter has a resistance of 24,000,000 ohms. He also described wire-wound resistances which he had used. R. L. Benbroeck described the method used in calibrating the 132-kv. potentiometer for phase angle. G. Thomas brought out the large volume of apparatus necessary in employing the resistance train method of measurement at high voltage and suggested that the capacitance train which involves much smaller equipment might be used with good results. Mr. Weller replied that he had considered the latter method but had not adopted it because capacity measurements are not as accurate as resistance measurements and capacitors tend to amplify harmonic voltages.

Commenting on the paper by Messrs. Stoller and Power, F. A. Byles claimed that a vibrating contact regulator specially constructed when used with saturated-core transformers will give very close regulation, that is 5 per cent above and below normal voltage.

To Members Going Abroad

Members of the Institute who contemplate visiting foreign countries are reminded that since 1912 the Institute has had reciprocal arrangements with a number of foreign engineering societies for the exchange of visiting member privileges, which entitle members of the Institute while abroad to membership privileges in these societies for a period of three months and members of foreign societies visiting the United States to the privileges of Institute membership for a like period of time, upon presentation of proper credentials. A form of certificate which serves as credentials from the Institute to the foreign societies for the use of Institute members desiring to avail themselves of these exchange privileges may be obtained upon application to Institute headquarters, New York.

The societies with which these reciprocal arrangements have been established and are still in effect are: Institution of Electrical Engineers (Great Britain), Societe Francaise des Electriciens (France), Association Suisse des Electriciens (Switzerland), Associazione Elettrotecnica Italiana (Italy), Koninklijk Instituut van Ingenieurs (Holland), Verband Deutscher Elektrotechniker E. V. (Germany), Denki Gakkwai (Japan), Norsk Elektroteknisk Forening (Norway), Elektrotechnicky Svaz Ceskoslovensky (Czechoslovakia), and The Institution of Engineers, Australia (Australia).

The 1929 Year Book Ready

The 1929 issue of the Institute's Year Book is ready for distribution and may be obtained upon application at headquarters. The book contains both alphabetical and geographical cataloging of Institute members, revised to January 1, 1929,

together with copy of By-Laws, Constitution, list of officers, list of committees, and other information pertinent to Institute activities.

AMERICAN ENGINEERING COUNCIL

REPORT ON STREET SIGNS, SIGNALS, AND MARKINGS

The report of the Council's Committee on Street Traffic Signs, Signals, and Markings is now off the press and is causing widespread interest and favorable comment. Many requests for copies are being received by L. W. Wallace, Executive Secretary. It is the ambition of the committee to have its recommendations carefully considered and adopted as a part of all national municipalities and in order to accomplish this the suggestions are made (a) that in each locality where there is a local engineering section, the president be supplied with a copy of the report with a recommendation that he in turn, through a local committee of his own, disseminate the information contained in the report; in communities where there is no local society, the local section of the national society would exercise this same method of information; in municipalities where there is neither local society nor local section, that there be an endeavor to organize a local section through some local engineer or civic organization. The Council offers to supply such local committee with a necessary number of reports and such other guidance as is required. It would appear that now, when traffic matters are so ultra important every community would benefit greatly by organizing to avail itself of this offer of the Council.

BOOK REVIEWS

Distribution of Electricity by Overhead Lines. By William T. Taylor. London, Charles Griffin & Co., Ltd. 265 pages., 6 by 9 in., cloth, illustrated, 1928. Price $6.50.

The book is intended for engineers engaged in planning, constructing and operating overhead distribution lines, and the practises presented are of general application and are not confined specially to English usage. Many references to American Standards are given. It is divided into seven chapters, the first two of which cover the history, study of the location, and general principles of design of a-c. distribution lines. The author considers the three-phase four-wire system the ultimate method of distribution. A very complete chapter on the calculations for the design of lines is given, followed by a chapter on the various mechanical details of design. The book concludes with a chapter on distribution maintenance.

Storage Batteries. By Morton Arendt. New York, D. Van Nostrand Company, Inc., 285 pages, 6 by 9 in., cloth, illustrated, 1928. Price $4.50.

The author's lectures to engineering students at Columbia College and to officers at the U. S. Submarine School over a number of years is the material from which the book has been developed. It is essentially a book for the practical man who is interested in the application, maintenance and operation of storage batteries. The complicated chemistry of the storage battery has only been included sufficiently to explain the characteristics and reactions of the cells. A brief introduction and history of the storage battery is followed by a chapter on general theory which is very simply explained. The method of manufacture and forming lead plates and the sulphuric acid electrolyte are described, and the factors influencing capacity and efficiency are discussed. A chapter on the details of construction of the lead cell is followed by a very practical chapter on installation, operation, and maintenance. Other subjects treated are the Edison nickel-iron cell, storage battery testing and numerous industrial applications.

Finding and Stopping Waste in Modern Boiler Rooms, edited by George H. Gibson. Philadelphia, Pa., Cochrane Corporation. 804 pages, 5 by 7 in., flexible cloth, illustrated 1928. Price $3.00.

This is the third edition of this steam plant manual, which has been brought up to date and includes new matter which makes it nearly double the size of the earlier editions. It comprises a reference book on steam plant which has been compiled from papers read before engineering societies, books, technical periodicals, etc., arranged in convenient form for managers and operators interested in boiler room efficiency. Five sections cover the subjects of fuels, combustion, heat absorption, boiler efficiency, and testing. The final section discusses heat balancing, water conditioning and protection from scaling and corrosion.

Mechanics for Engineers, by Julian C. Smallwood and Frank W. Kouwenhoven. New York, D. Van Nostrand Co., Inc., 185 pages, 6 by 9 in., cloth, illustrated, 1928. Price $2.50.

This book has been specially arranged for the use of engineering students by including a limited treatment of statics and kinematics and omitting such subjects as do not apply directly to an engineering course. As the average student cannot assimilate a comprehensive course in mechanics in the limited time usually allotted to it the engineering curricula, only the most essential subjects have been included. Emphasis is placed on the physical interpretation of the equations and laws presented. Intersperced throughout the book are problems on the various subjects, the first one being in each case worked out, followed by others for the student to solve. Answers to all the problems are given. For courses involving a time too limited to cover the entire text, certain articles designated by italic numbers are recommended for omission.

Radio, by Elmer E. Burns. New York, D. Van Nostrand Co., Inc. 255 pages, 5½ by 8 in., cloth, illustrated, 1928. Price $2.00.

This is essentially a book of first principles and is adopted to the requirements of students and experimenters in radio. The work is arranged to give first the fundamental electrical theory of radio and then a study of the different parts and their application to radio circuits. The mathematics employed are very simple and the book is written so as to be easily understood by the non-technical reader. The book starts with an explanation of simple receiving circuits, followed by chapters on electric batteries, magnetic action of electric currents, and electric circuits and Ohms law. This is followed by alternating-current phenomena and laws, and descriptions of the component parts and their functions in receiving circuits. The last chapter is on radio measurements. The book is prefaced by a "suggested course of study" which will be helpful to the student.

Laws of Management Applied to Manufacturing, by L. P. Alford. New York, The Ronald Press Co. 266 pages, 5½ x 8½ in., cloth, illustrated, 1928. Price $4.00.

The basis of this book is a paper by the author presented in 1926 to the American Society of Mechanical Engineers. The author has formulated about 50 laws which have been developed during many years of experience in manufacturing processes. Each of these fundamental laws or fundamental principles in manufacturing organizations is discussed fully and examples are cited showing the applicability of the law to specific instances of manufacturing, and the gains and improvements secured thereby. The book opens with a chapter on progress in manufacturing which calls attention to the developments of mass production, merging of large corporate units, discovery and application of new products, and the very common use of articles which a short while ago were considered luxuries. Progress in management is shown to have occurred as the result of the application of fundamental laws, which are discussed in the remaining chapters. The book is written in popular style and should be of interest to all factory executives.

Practical Television, by E. T. Larner. New York, D. Van Nostrand Co., Inc. 5½ by 8½ in., cloth, illustrated, 1928. Price $3.75.

This work presents a very interesting story of the general principles on which television is founded and treats the subject

in a manner which can be readily understood by the non-technical reader. The book distinguishes clearly between television, or the instantaneous transmission of images, and telephotography, or the transmission of photographs by wire or radio—two related subjects which are frequently confused. A brief summary of the early attempts in television and the historical aspects of the subject is given, and the selenium cell, which is the basis of all the early experiments in this field, is described. The photoelectric cell is the next development treated and one chapter is devoted to Continental and American researches in television. The subjects of optics, television technique, and recent developments conclude the book. The subject is probably one of the most fruitful in prospects for the research worker.

Graphical Analysis of Alternating-Current Circuits, by Frederick W. Lee. Baltimore, Md. F. W. Medaugh, Civil Engineering Dept., The Johns Hopkins University. 76 pages, 6 x 9¼ in., cloth, illustrated.

It is of great advantage to the Student and Engineer to be able to visualize equations by means of graphs and this book develops a graphical method of solving alternating-current problems which is based on the analytical method as a foundation. It is divided into seven chapters, the first two of which are devoted to the principles of vector analysis and loci diagrams. The remaining chapters show graphical solutions of the fundamental equations of alternating current circuits. The book will be found very useful to the student by enabling him to visualize the full possibilities of a circuit without recourse to tedious solutions of long equations.

PERSONAL MENTION

Edward T. Newton has resigned his position as Assistant Electrical Engineer of the American Brass Company at Waterbury, Connecticut, to accept an appointment as Junior Examiner in the United States Patent Office at Washington, D. C.

W. L. Bird has just been appointed Vice-President of the Kaminitiquia Power Company of Canada. Mr. Bird is a Fellow of the Institute, Past-President of the Canada Electrical Association, and a member of the Hydraulic Committee of the National Electric Light Association.

K. W. Johansson, Switchboard Engineering Department, Westinghouse Electric International Company, sailed yesterday on the North German–Lloyd liner *Meunchen* for Cherbourg, whence he will proceed to Barcelona to supervise the installation of the electrical equipment which is one of the features of the International Exposition at Barcelona this summer.

Hamilton McRary Jones, manager of the Department of the Americas of the Westinghouse Electric International Company, has recently resigned from that organization to accept a position as General Manager of the International Power Company and Vice-President of the Montreal Engineering Company in Montreal, Canada.

H. Hobart Porter, President of the American Water Works and Electric Company, and of the Brooklyn City Railroad Company, has been elected to succeed L. B. Stillwell as Chairman of Engineering Foundation. Mr. Porter is also chairman of the Board of the West Penn Electric Company and Vice-President of the Queensboro Gas and Electric Company. He is also a member of the Division of Engineering of the Executive Board of the National Research Council and a Trustee of Columbia University.

R. J. S. Pigott who for three years was Mechanical Engineer with Stevens & Wood, Incorporated and later Consulting Engineer with Public Service Corporation of New Jersey Production Company and Smoot Engineering Corporation has returned to the Stevens & Wood organization as Consulting Mechanical Engineer. For several years Mr. Pigott was Chairman of the A. S. M. E. Main Research Committee and has had wide experience with industrial and power plants. In his new assignment he will devote his time mainly to solving the problems of industrial companies both in matters of power and production.

Obituary

Charles Schenck Bradley, whose biographical sketch was published in the May and July 1928 issues of the Institute Journal, under the heading of "Some Leaders of the A. I. E. E., died Sunday, March 3, at St. Luke's Hospital, New York, N. Y. He was recently made an Institute Member for Life.

Cecil F. Wilson, Engineer of the New York Telephone Company and an Associate of the Institute since 1918, died in St. Luke's Hospital of pneumonia, January 22, 1929.

Born February 11, 1889 at Roseville, Ohio, Mr. Wilson was graduated from the Ohio State University in 1911 with a degree of M. E. in Electrical Engineering, and was elected a member of the Sigma Xi Society. During the summer of 1910 he was made switchboard operator of the Pittsburgh Plate Glass Company, Crystal City, Missouri, where he also had experience in general power electrical repair work. After graduation he joined the New York Telephone Company's office at Newark, New Jersey, as Telephone Engineer of the New Jersey Division, and in 1917 he was appointed Division Equipment Engineer. After a year's service there he was transferred to the New York Office as Engineer in the Engineering Department at 195 Broadway and remained there the rest of his period of service with the Company.

Harold P. Thomas, Foreman of the Test Department of the Lincoln Electric Company of Cleveland, Ohio, died February 7, 1929 at his home, East Cleveland, Ohio.

Mr. Thomas was born at Pittston, Pa., December 18, 1885. After passing through the grade schools, high school and preparatory school of his home town, he spent three years in the Medical School at the University of Pennsylvania. From 1902 to 1906, he was successively electrician's helper, colliery electrician and division electrician for the Lehigh Valley Coal Company, at Wilkes-Barre and for the next three years during the summer months continued this work with it. From 1910 to 1914 he was engaged in electrical repair work, following this with an appointment as Foreman of Winding, Assembling and Testing departmental work for the Dyneto Electric Company of Syracuse, New York. In 1917 he became Maintenance Electrician for the Willard Storage Battery Company, of Cleveland, Ohio; in 1918, neer for the American Ever Ready Company, Cleveland, Ohio and in 1921, the year in which he became an Associate of the Institute, he was appointed to the position of Test Inspector for for the Lincoln Electric Company.
Tester and final inspector of all motors manufactured by the Van Dorn Electric Tool Company, Cleveland, Ohio; in 1920, Foreman of the Assembly of Electric Fans and Small Motors for Adams Bagnall Electric Company; in 1920, Powerhouse Engi-

FERDINAND FOCH, Marechal de France—at 138 rue de Grenelle, Paris, March Twentieth, Nineteen Hundred and Twenty-Nine.

Elected an Honorary Member of the Institute and other Founder Societies 1921.

It will be remembered by Institute members that Marshall Foch visited the Engineering Societies Building, New York, March 13, 1921, the date under which a medallion of commemoration was mounted on the West wall of the Main Foyer, just to the right of the case containing the regimental colors of the Twenty-Fourth Engineers, Service of Supplies, A. E. F., and the Twenty-Seventh Engineers, American Engineering Troops, Advance Section, A. E. F., who served under the Marshall at Marne-Aisne, Aisne-Vesle, St. Mihiel, and the Argonne-Meuse.

He died as he lived—a great man.

A. I. E. E. Section Activities

GROUP ACTIVITIES PROPOSED IN NEW YORK SECTION

A movement is now under way within the New York Section to divide the section membership into groups according to the field in which they are interested. At the present time four such groups are in view, namely; the Power group, the Communication, Transportation and Illumination groups. It is proposed that these individual groups will each hold a number of meetings during each administrative year for the presentation and discussion of papers of particular interest to them. The groups will be so arranged and divided into committees as to be able to handle completely their own meetings and affairs in general. This will provide an opportunity for a large number of Section members to take part in Section affairs, and permit also for wider discussion participated in by men who ordinarily do not get such opportunity at the large general monthly meetings. The monthly meetings on subjects of general interest to the entire Section membership will be continued. The Power group has set the date for its first meeting for April 10th and a program is being prepared. This group is under the chairmanship of George Sutherland of the New York and Queens Electric Light and Power Company. The chairman of the other three groups are as follows: H. S. Sheppard, Communication; T. R. Langan, Transportation; E. E. Dorting, Illumination.

FUTURE SECTION MEETINGS

Cleveland

Communication. Electric League Rooms, Hotel Statler. April 18.

Annual Dinner Meeting. Speaker: R. F. Schuchardt, President, A. I. E. E. Electric League Rooms, Hotel Statler. May 23.

Columbus

Joint meeting with Ohio State University Branch. Smoker and buffet luncheon. April 26.

Power Supply for Railway Signals and Automatic Train Control, by C. F. King, Jr., Westinghouse Electric & Mfg. Co. Afternoon session, 2:30 p. m., Ohio Power Co. Building, Newark, Ohio. Inspection of Pennsylvania Railroad automatic train control substation in Newark. Evening session, 6:30 p. m., Chittenden Hotel, Columbus. Ladies Night. Election of officers. May 24.

Detroit-Ann Arbor

Relays, by H. W. Collins, Detroit Edison Co., and J. R. North, Commonwealth Power Corp. Detroit, April 16.

Lehigh Valley

National Electric Code, by A. R. Small, and

Electrical Features of Mack Plant, by W. P. Mitchell. Americus Hotel, Allentown. April 19.

Power Transmission, by A. O. Austin. Inspection of Hazleton Service Depot. Altamont Hotel, Hazleton. May 10-11.

Madison

Some Recent Research Developments of the Westinghouse Electric & Mfg. Co., by C. E. Skinner, Asst. Director of Engg. April 16.

Election of Officers and showing of Baron Shiba's high speed film. May 22.

Pittsburgh

Ladies Night. Meeting and Dinner Dance. May 14.

Pittsfield

Demonstration of artificial lighting and high-voltage phenomena. Pittsfield Works, General Electric Co. Joint with Engg. Society of Western Mass. April 16.

St. Louis

April 17.
May 15.

Saskatchewan

Annual Meeting. Election of Officers. April 26.

Seattle

Joint meeting with University of Washington Branch. Program under direction of Prof. George L. Hoard, University of Washington. April 16.

Competitive Papers. May 21.

Sharon

Youngstown, Ohio. May 4.

Toronto

Vacuum Tube Devices, by J. V. Beisky, Westinghouse Electric & Mfg. Co. Hamilton Canadian Westinghouse Company Auditorium. April 21.

Ladies Night. Election of Officers. May 10.

Utah

Recent Developments in the Telephone Field, by H. W. Oddie, Transmission and Protection Engr., M. S. T. & T. Co. April 15.

Joint meeting with University of Utah Branch. May 13.

Vancouver

Concentrators at Trail, by H. A. Moore, Toronto. May 7.

Washington

High-Capacity Mercury Arc Rectifiers, by F. A. Faron, General Electric Co. May 14.

PAST SECTION MEETINGS

Boston

Transatlantic Telephony, by Dr. J. O. Perrine, American Tel. & Tel. Co. Buffet supper. February 12. Attendance 150.

The Passamaquoddy Tidal Project, by M. B. Pike, Dexter P. Cooper, Inc. March 5. Attendance 125.

Chicago

The Electrical Industry in America, by Paul S. Clapp, Managing Director, N. E. L. A. Joint meeting with Electrical Section, Western Society of Engineers. Dinner to the speaker and Executive Committee. January 21, Attendance 300.

Boulder Dam Project. R. F. Schuchardt, President, A. I. E. E., introduced the speaker, Prof. Daniel W. Mead, Consulting Engineer and one of the three engineers appointed by President Coolidge to report on the economic and engineering phases of this project. Slides. Joint meeting with Electrical Section, Western Society of Engineers, preceded by a dinner in honor of the speaker. March 11. Attendance 560.

Cincinnati

High-Voltage, High-Frequency Phenomena, by F. W. Peek, Jr., Mgr., Transformer Engg. Dept., General Electric Co., Pittsfield, Mass. Joint meeting with Engineers' Club of Dayton, Ohio. February 12. Attendance 200.

Cleveland

The Development of Power Machinery, by F. D. Newbury, Mgr., Power Engg. Dept., Westinghouse Electric & Mfg. Co. Slides. A dinner to the speaker preceded the meeting. February 21. Attendance 60.

Columbus

The Influence of Recent Lightning Investigations on Transmission Line Development, by C. L. Fortescue, Consulting Transmission Engr., Westinghouse Electric & Mfg. Co. Illustrated. A short article on the new Deion Circuit Breaker was read by Prof. W. L. Everitt, Dept. of Electrical Engineering, Ohio State University. February 8. Attendance 45.

Connecticut

New England Power Systems Interconnections, by C. W. Mayott, Mgr., Connecticut Valley Power Exchange. The meeting, held at Norwich, was preceded by three reels of moving pictures—"Current in the Telephone Circuits," "Selection and Gathering of Long Leaf Pine Poles," and "Apparatus for Transmission of Pictures." January 15. Attendance 63.

Electrical Development in the Province of Ontario, by P. A. Borden, Development Engr., The Bristol Company, and

Electrolytic Condensers, by F. W. Godsey, Jr., Yale University. Meeting held at Waterbury, February 26. Attendance 36.

Dallas

Televox, by J. L. McCoy, Westinghouse Electric & Mfg. Co. February 4. Attendance 101.

Electric Welding of Steel Buildings and Bridges, by F. P. McKibben, Consulting Engr., General Electric Co. Slides. Brief reports concerning program of Regional Meeting to be held in Dallas. Local Sections of four other national societies invited. February 20. Attendance 179.

Denver

Recent Laboratory Developments in the Communication Art, by R. B. Bonney, Educational Director, The Mountain States Telephone and Telegraph Co. Slides and educational sound pictures demonstrating carrier telephony. Reports of the Membership and Program Committees. Dinner. February 15. Attendance 60.

Detroit-Ann Arbor

Light Sources in General, by Frank Benford, Research Laboratory, General Electric Co. Business session. President R. F. Schuchardt's message in the January 1929 issue of the JOURNAL was read and discussed. Joint meeting with Michigan Section, Illuminating Engineering Society, preceded by a dinner. February 19. Attendance 100.

Erie

Aviation As a Commercial Proposition, by G. G. Jury, Cleveland Traffic Representative of Stout Air Service. February 19. Attendance 100.

Fort Wayne

Railroad Electrification, by J. V. B. Duer, Elec. Engr., Pennsylvania Railroad. Motion pictures were shown before and refreshments served after the meeting. February 28. Attendance 55.

Houston

Televox, by J. L. McCoy, Westinghouse Electric & Mfg. Co. Demonstration. February 7. Attendance 180.

Electric Welding of Steel Bridges and Buildings, by F. P. McKibben, Consulting Engr., General Electric Co. Illustrated. Joint meeting with Houston Engineers Club and Sections of seven national societies. Meeting preceded by a dinner. February 21. Attendance 160.

Indianapolis-Lafayette

Aircraft Development, by Major J. E. Fickel, Wright Field, Dayton, Ohio., and

Present Status of Electric Welding of Structural Work, by A. M. Candy, Welding Engr., Westinghouse Electric & Mfg. Co. Motion pictures of aircraft development. Joint meeting with Indiana Engineering Society. February 7. Attendance 55.

A New Hot Cathode Ray Oscillograph and Its Application to Lightning and Switching Surges, by R. H. George, Research Associate, Engineering Experiment Station, Purdue University. Demonstration. March 1. Attendance 105.

Ithaca

Frequency Measurement and Control, by Dr. Leo Behr, Leeds & Northrup Co. Demonstration of recording frequency meter. February 15. Attendance 150.

Kansas City

Some Problems of the Gas Industry, by Maj. T. J. Strickler, Vice-President and General Mgr., Kansas City Gas Co., and

Radio Transmission, by R. G. McCurdy, Mgr., Radio Dept., Graybar Electric Co., Kansas City. Coffee and sandwiches served. February 26. Attendance 70.

Lehigh Valley

Welding—Welds—Welders, by Chas. Schenck, Prof. C. D. Jensen and H. J. Bowles. Slides. Dinner was served, during which Prof. Morland King, Lafayette College, spoke on the Winter Convention. Prof. S. S. Seyfert, Lehigh University, gave a description of the Packard Electrical and Mechanical Building. Joint meeting with Engineers Club of the Lehigh Valley and Lehigh University Student Branch at Lehigh University. February 23. Attendance 163.

Los Angeles

Telephone Communication over Deep Sea Submarine Cables, by H. W. Hitchcock, Chief Engineer, Southern California Telephone Co. Preceded by a dinner. February 5. Attendance 90.

Inspection trip to the Mutual Office, Southern California Telephone Co. February 9. Attendance 47.

Annual joint meeting with Student Branches of California Institute of Technology and the University of Southern California. (See complete report in Student Activities department. March 5. Attendance 240.

Louisville

Network Broadcasting, prepared by G. A. Duncan, Long Lines Dept., A. T. & T. Co., and presented by M. W. Keyser, District Transportation Engr. Dean B. M. Brigman, University of Louisville, described the A. I. E. E. National and Regional Prizes. J. Emmett Graft, Chief Operator, Station WHAS, and Milo Utterback, Assistant Operator, described in detail the operation of the station. January 31. Attendance 40.

Inspection trip to Corhart Refractories Company Plant. S. W. Schroeder, Chief Chemist, conducted a tour of the Plant. After the inspection trip the meeting adjourned to the office where Mr. Schroeder answered questions regarding material produced and its applications. Guests of A. S. M. E. February 21. Attendance 21.

Lynn

Present Day Aeronautics, by Lieut. A. F. Hegenberger. Lantern slides and moving pictures. February 20. Attendance 325.

Inspection trip to Everett Water Gas Plant of Boston Consolidated Gas Co. D. C. Reynolds, Chief Engr., conducted party through the plant. March 2. Attendance 30.

Manufacture of City Gas, by Edwin R. Clarke, Asst. Supt., Lynn Gas & Electric Co.;

Gas, the Better Fuel, by W. A. Oates, Heating Engr., Lynn Gas Gas & Elec. Co.;

Radio Frequency Standardization, by R. S. Davidson, Thomson Research Laboratory, General Electric Co., and

Quiet Induction Motors, by L. E. Hildebrand, Motor Engg. Dept., General Electric Co. Local convention night. March 6. Attendance 70

Madison

The Photoelectric Cell and Its Uses in Communication, by Dr. J. O. Perrine, American Tel. & Tel. Co. Demonstrations. Meeting preceded by a dinner in honor of the Bell System representatives. February 19. Attendance 360.

Minnesota

Banquet meeting of the Third Annual Engineering Conference of the North Central Electric Association. Members of Minnesota Section, A. I. E. E. invited. Talk by L. W. W. Morrow, Editor, *Electrical World*. January 21. Attendance 203.

Nebraska

Delayed Speech and Other Recent Discoveries and Inventions of the Bell Telephone Laboratories, by S. P. Grace, Assistant Vice-President, Bell Telephone Laboratories, Inc. Demonstrations. February 19. Attendance 1800.

Oklahoma

Commercial Applications of Carrier Currents to Transmission Lines, by C. E. Bathe, Oklahoma Gas and Electric Co. B. D. Hull, Vice-President, gave an outline of the many features of the Regional Meeting to be held in Dallas May 7-9, and urged that as many as possible attend. Chairman instructed to appoint a committee of judges to determine the best and second best student papers presented for prizes at the 1929 joint meeting of the Section and the two Student Branches in Oklahoma. February 27. Attendance 23.

Philadelphia

Railroad Electrification in the Philadelphia Area, by J. V. B. Duer, Elec. Engr., Pennsylvania Railroad, and N. E. Funk, Ass't. General Mgr., Philadelphia Electric Co. Dinner preceded the meeting. February 11. Attendance 275.

Pittsburgh

The Extinction of an Alternating-Current Arc, by Dr. Joseph Slepian, Consulting Research Engr., Westinghouse Electric & Mfg. Co. The paper was followed by a demonstration of the Deion Circuit Breaker at the High Power Laboratory. Guests of Westinghouse Electric & Mfg. Co. at dinner. Joint meeting with Electrical Section, Engineers Society of Western Pennsylvania. February 12. Attendance 570.

Pittsfield

My Life with the Foreign Legion, by Bennett J. Doty. The speaker was entertained at dinner prior to the meeting. February 5. Attendance 800.

Conowingo and 220-Kv. Interconnection Developments, by R. A. Hentz, Engr., Philadelphia Electric Co. February 19. Attendance 80.

What's Coming in Aviation, by W. B. Stout, President, Stout Metal Airplane Co. (Division Ford Motor Co.). March 5. Attendance 500.

Portland

Economics of Interconnection of Power Systems, by O. L. LeFever, General Supt., Northwestern Electric Co. Film of the Great Northern Tunnel Construction. Refreshments. February 26. Attendance 70.

Providence

The Narragansett Electric Company's System, by J. W. Young, Elec. Engr., Narragansett Electric Co. Refreshments. March 5. Attendance 130.

St. Louis

Annual Dance. Attendance prizes awarded to Gordon W. Gerell, C. J. Embree and Raymond C. Hase. February 20. Attendance 108.

San Francisco

Electric Welding of Steel Bridges and Buildings, by F. P. McKibben, Consulting Engr., Black Gap, Pa., and Schenectady, N. Y. Joint meeting with Sections of A. S. C. E., A. S. M. E., American Welding Society and American Institute of Architects. Dinner in honor of Mr. McKibben. January 25. Attendance 482.

Seattle

Welding of Steel Buildings, Bridges and Other Structures, by F. P McKibben, Consulting Engr., Black Gap, Pa., and Schenectady, N. Y. A resolution was passed placing the Section on record as opposed to the proposed Engineers License Law for the State of Washington. All local engineering organizations invited. A comedy feature "A Night on Test" was presented by Ex-G. E. Test Men. February 12. Attendance 220.

Sharon

The Deion Circuit Breaker, by B. P. Baker, Westinghouse Electric & Mfg. Co. Moving pictures of China. February 5. Attendance 136.

The Role of Physics in Industry, by Dr. L. O. Grondahl, Director of Research, Union Switch & Signal Co. Moving picture—"Driving the Longest Railroad Tunnel in the Western Hemisphere." March 5. Attendance 80.

Spokane

Power Factor from a Central Station Viewpoint, by W. S. Hill, General Supt., Gray's Harbor Railway & Light Co. Mr. Baughn, Chairman of the Meetings and Papers Committee, reported that the April meeting will be held in Moscow as a joint meeting of the Section and Student Branches of the University of Idaho and Washington State College. February 21. Attendance 16.

Springfield

Making Sound Visible and Light Audible, by J. B. Taylor, Consulting Engr., General Elec. Co. Slides and demonstrations. January 14. Attendance 117.

The Experiences of an Electrical Engineer in Central and South America, by S. Q. Hayes, General Engr., Westinghouse Electric & Mfg. Co. Delineascope pictures. February 18. Attendance 70.

Syracuse

Airport Lighting, by A. H. Clarke, Illumination Engr., Crouse Hinds Co. Miniature air port was displayed. February 25. Attendance 135.

Toledo

Televox, by J. L. McCoy, Westinghouse Electric & Mfg. Co. Demonstrations. Chairman Featherstone read a description of Baron Shiba's camera, illustrating it with lantern slides. The following motion pictures shown: "Driving the Longest Railroad Tunnel in the Western Hemisphere;" Baron Shiba's film on airplane research. Meeting preceded by a dinner at which Vice-President J. L. Beaver gave a short talk. Joint with A. S. M. E. Ladies invited. March 7. Attendance 500.

Toronto

Deion Circuit Breaker, by H. M. Wilcox, Westinghouse Electric & Mfg. Co. Slides. February 8. Attendance 95.

Gatineau-Toronto Power Line, by A. E. Davison, Engg. Dept., Hydro-Elec. Power Commission. February 22. Attendance 105.

Urbana

Arcing Phenomena at the Contact of a Switch, by R. E. Tarpley, Research Graduate Assistant, Dept. of Elec. Engg., University of Illinois. Slides. February 13. Attendance 25.

The Photo electric Cell and Its Uses in Communication, by Dr. J. O. Perrine, American Tel. & Tel. Co. February 21. Attendance 365.

Utah

The Photo electric Cell and Its Applications, by Dr. H. T. Plumb, Engr., General Electric Co., Salt Lake City. Demonstrations. February 18. Attendance 100.

Vancouver

Annual student meeting. (See complete report in Student Activities dept.). March 5. Attendance 35.

Washington

Automatic Train Control, by W. H. Reichard, Consulting Elec. Engr., General Railway Signal Co. Slides. Refreshments served. Dinner in honor of the speaker. February 12. Attendance 173.

A. I. E. E. Student Activities

STUDENT BRANCH CONVENTION AND NEW YORK SECTION MEETING

On April 26th the New York Section of the Institute will hold its annual Student Branch Convention and regular monthly Section meeting. The students from the eight colleges in the New York District will present papers in competition for the $25.00 prize offered yearly by the Section. The presentation of the student papers will take place during an afternoon session held in the Engineering Building, 33 West 39th Street, New York. A committee of judges appointed by the Executive Committee will make the award. The morning of the 26th will be devoted to inspection trips arranged by and for the students. Immediately following the afternoon session there will be a student dinner at which it is hoped to have as a speaker some very prominent engineer. At previous conventions some 500 students have participated.

In the evening the New York Section will hold its regular meeting at which Hugh Cooper, well known consulting engineer will deliver an interesting talk on hydroelectric developments abroad. Complete details relative to the student meeting and as to the evening session will be available later. The regular meeting will take place in the Engineering Auditorium at 8.15 p. m.

STUDENT CONVENTION HELD IN PHILADELPHIA

The Fifth Annual Student Convention of the Eastern part of District No. 2 was held at the Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, on March 11, 1929. Beginning at 11:00 a. m., the following program was presented:

Address of Welcome, Dr. Harold Pender, Dean, Moore School of Electrical Engineering.

The Klydonograph, H. G. Wiest, '29, Lehigh University.

Mercury Arc Rectifiers, D. B. Spangler, '29, Chairman, Swarthmore College Branch.

Cathode Ray Oscillograph, Otto Meier, Jr., '29, University of Pennsylvania.

Some Developments in Power Plant Frequency Control, D. D. Lewis, '29, Haverford College.

At a luncheon meeting held in the Christian Association building, a talk was given by Mr. Sidney K. Wolf, Acoustic Engineer, Electrical Research Products, Inc., on the subject *Movietone Recording and Reproducing Equipment.*

The entire party then attended the afternoon show at the Fox-Locust Theatre and, after the close of the program, inspected the movietone apparatus, under the direction of Mr. S. K. Wolf and the operators.

After the return to the Moore School building, a talk on *Psychology of Switchboard Arrangement* was given by William W. Braunwarth, '29, University of Pennsylvania, and this was followed by an inspection of the electrical engineering laboratories.

The dinner and evening program were held in the Christian Association building, and the following two addresses were given:

Student Branch Activities, H. H. Henline, Assistant National Secretary.

Address, Dr. George W. McClelland, Vice-Provost, University of Pennsylvania.

The orchestra of the Engineers Club of Philadelphia furnished music during the evening and, after the above addresses, skits were given by students of University of Pennsylvania, Lehigh University, and Drexel Institute. At the opening of the morning session, the following judges were appointed to award the prizes for the technical papers: D. M. Way, Chairman, Drexel Institute Branch; W. V. G. Eakins, Chairman, Princeton University Branch, and Mr. Clay of Lafayette College. During the evening program the decisions of the judges were announced, and T. E. Manning, Chairman, University of Pennsylvania Branch, presented prizes as follows: $10.00 each to H. G. Wiest and Otto Meier; $5.00 each to D. B. Spangler and D. D. Lewis.

The Convention was sponsored by the Philadelphia and Lehigh Valley Sections, and the following schools participated: Delaware, Drexel, Haverford, Lafayette, Lehigh, Pennsylvania, Princeton, and Swarthmore.

The attendance at the various events varied from about 165 to 190.

VANCOUVER SECTION HOLDS ANNUAL STUDENT MEETING

The annual student meeting of the Vancouver Section was held at the University of British Columbia on the evening of March 5, 1929. After a talk by C. W. Colvin, Chairman of the Section, on the advantages of Student enrolment in the Institute, the following program was presented by seniors:

Some Applications of Thermionic Vacuum Tubes, Mr. Blackett.

Diesel Engines, Mr. Jagger.

Power Rectifiers, Mr. Morrison.

Modern Heavier-Than-Air Craft, Mr. Bishop.

Electrical Measuring Instruments, Induction Type, Mr. Dhami.

The papers were well presented, and the 35 persons present were pleased with the program.

ANNUAL JOINT MEETING OF LOS ANGELES SECTION WITH STUDENT BRANCHES

Continuing their plan of holding an annual joint meeting with a program supplied by students, the Los Angeles Section and California Institute of Technology and University of Southern California Branches met at the California Institute of Technology on the evening of March 5, 1929. During the early part of the evening, music was furnished by members of the Branches. After a dinner, the following program was presented:

Output and Power Factor of a Constant-Current Transformer, D. R. Stanfield, University of Southern California.

Effect of Frequency upon the Operation of the Electro-Magnetic Oscillograph, D. M. Wright and John Gilroy, University of Southern California.

Hoover, an Engineer President, Robert Good, University of Southern California.

Control Features of the Wind Tunnel, William Lewis, California Institute of Technology.

Following the presentation of the papers, high-voltage demonstrations were given in the million-volt laboratory, and there was a tour of inspection through the Aeronautics Building where the wind tunnel equipment was demonstrated. The attendance was 240.

MONTANA STATE COLLEGE BRANCH HAS RHODES SCHOLAR

Matt Pakkala, senior in electrical engineering at Montana State College, has been awarded the Rhodes Scholarship to Oxford University, England. He was selected from a group of ten candidates from the colleges in the state of Montana, and will begin his work at Oxford next October to read for a degree in mathematics which he expects to receive after three years' study. Mr. Pakkala is the first student of Montana State College to receive the Rhodes Scholarship, and is considered to be the most brilliant mathematician who ever attended that school. The authorities at Oxford have granted him senior standing without examination.

STUDENT BRANCH ACTIVITIES

Thos. C. McFarland

Counselor University of California Branch, and Chairman Committee on Student Activities, Pacific District

It is generally recognized that the great problem in the conduct of A. I. E. E. Student Branches is to secure a larger participation in the Branch affairs by the student members. The real solution is, doubtless, to make the meetings of sufficient interest to all the members that they will voluntarily be active. But how can the interest of the individual student be increased? How can meetings be conducted so that the members will derive the maximum benefit?

There is an old saying to the effect that he who puts the most into the project gets the most in return. There may be exceptions but when the project happens to be an organization such as the American Institute of Electrical Engineers there is no denying the validity of that observation. In the Branches those taking the greatest interest are chiefly the ones having responsibilities. The officers and committee chairmen take the greatest interest and, consequently, derive the most good. If the membership is very small the work of the Branch can possibly be distributed so that all will feel they are contributing something. With the larger Branches, however, only a relatively small number can serve in this way. What shall we do to interest the majority?

In the University of California Branch the problem of maintaining interest is a very real one for the membership is quite large. In an attempt to solve this the following plan has been adopted. At the time of the initiation an expression of opinion is obtained from each of the members as to the topics that interest him most. This is done through the medium of a questionnaire in which four questions are asked. These questions are:

1. In which of the following activities are you most interested? (A tabulation of activities about as indicated by the list of Institute Technical Committees followed).

2. Upon which of the above topics (or some phase thereof) are you willing to prepare a paper for a Branch meeting?

3. What type of industry or what specific plants would you like to visit during the year?

4. On which of the following committees would you prefer serving? (A list of the Branch committees follows).

The answers to the fourth question make possible the appointment, by the Chairman, of committees that may be expected to function. From the first and second questions material is obtained that enables the Program Committee to know what type of meetings are most likely to be successful and also to definitely plan a program for the whole semester. The interests as

expressed in the answers to these questions can be grouped into a small number of general headings thus permitting the committee to schedule a program in which each group will be represented. It is recommended that not only should the speakers for the meetings be assigned but also that at least two men be designated to contribute oral discussion on each paper. Furthermore, the choice of outside speakers and of motion pictures or of slides is influenced by the answers given to these questions.

The results thus far indicate that the plan has considerable merit. The worth of the questionnaire has been fully demonstrated. There has been a large amount of material from which to choose, thus making it easier for the officers and committees to function. (Unless the members will sincerely cooperate and answer all the questions the plan is doomed to an early failure). Unfortunately, the plan has not been strictly adhered to in the conduct of meetings and there has not been the improvement that was hoped for. Too few of the members have been asked to give papers and to contribute discussion, with the result that the original intent of the plan has been largely defeated. It is hoped that in another semester this difficulty can be ironed out.

PAST BRANCH MEETINGS

Municipal University of Akron

Inspection trip to the automatic telephone exchange at Canton. March 6. Attendance 20.

Alabama Polytechnic Institute

What the Young Engineer May Expect on Entering a Public Utility, by H. E. Cox, Vice-President, Birmingham Electric Co. February 15. Attendance 47.

Mexico, by A. Nieto, student;

Tesla Coils, by D. O. Baird, student, and

The New Method of Running Automobiles, by B. S. Burton, student. February 21. Attendance 39.

Outdoor Meters, by W. L. Cochran, student, and

Experiences with the Railroad, by W. P. Smith, student. C. T. Ingersoll, president of Eta Kappa Nu Chapter, presented the Eta Kappa Nu slide rule to Paul Break for the best article for the "Auburn Engineer" during his sophomore year. February 28. Attendance 38.

Discussion of plans for Engineers Ball. Mr. Bynum, student, read the constitution of the newly formed Engineers Club and it was accepted as read. March 7. Attendance 34.

University of Arizona

Electrically Operated Refrigerators, by C. K. Gieringer, student. January 9. Attendance 8.

High-Voltage Phenomena in Thunderstorms, by Jack Hopper, Chairman, and

Synchronized Production of Sound and Scene, by Gene Magee, student. January 16. Attendance 10.

Motion pictures entitled respectively "Induction Regulator," "Automatic Substations," and "Power Transformers." January 23. Attendance 9.

Tracing the Development of A. I. E. E., by Prof. J. C. Clark. February 6. Attendance 13.

Thomas Edison, by Frank Henderson, student. The following officers elected: Vice-Chairman, C. K. Gieringer; Secretary, Wm. Tremaine; Treasurer, Frank Henderson. February 13. Attendance 19.

George Westinghouse, by Carl Gieringer, student;

Samuel Morse, by Rickardo Manzo, student, and

The Photoelectric Cell, by Leo Killian, student. February 20. Attendance 17.

History of Mathematics, by Fred Denny, student;

Electrical Precipitation of Gas Streams, by Roy Goar, student, and

Electric Welding, by Stanley McKinley, student. February 27. Attendance 15.

Talking Motion Pictures, by Kenneth Kelton, student. March 6. Attendance 18.

University of Arkansas

Application of X-Rays to Engineering, by W. M. Roberts, Asst. Prof. of Physics. February 15. Attendance 13.

Armour Institute of Technology

The Movietone and the Photoelectric Cell, by L. S. O'Roark, Employment Director, Bell Telephone Laboratories, Inc. Joint meeting with Lewis Institute Branch. February 14. Attendance 910.

Neon Signs, by Mr. Lindsey, Federal Electric Co. February 25. Attendance 157.

Brooklyn Polytechnic Institute

Derivation of Rates, by G. W. Trapani, student, and

Tesla Coils, by F. Seymers, N. Y. & Q. Electric Light & Power Co. January 10. Attendance 43.

Electrical Measuring Instruments, by Mr. Corby, Weston Electrical Instrument Corp. Refreshments. February 13. Attendance 51.

Bucknell University

Prof. W. K. Rhodes, Counselor, gave a short talk on the development of Electrical Engineering at Bucknell and the installation of the Branch. The purpose of the meeting was to make the Freshman Engineering students better acquainted with Branch activities and with the upper classmen. February 12. Attendance 19.

Application of Electricity to the Iron and Steel Industry, by F. O. Schnure, Alumnus, Electrical Superintendent, Sparrow's Point (Md.) plant, Bethlehem Steel Co. Slides. February 21. Attendance 40.

California Institute of Technology

Business Meeting. March 5. Attendance 23.

University of California

Boulder Dam, by A. P. Davis. Initiation Banquet. Dean C. L. Cory acted as toastmaster. Prof. T. C. McFarland welcomed the new members and explained the purposes and functioning of the organization. G. A. Anderson gave a brief talk on Engineering Unity. Prof. F. H. Cherry presented pins to the twenty-two new members. Musical entertainment. February 28. Attendance 70.

Carnegie Institute of Technology

Electrical Power, Plant to Consumer, by M. C. Zilberman, student, and

Current and Voltage Distribution in Transmitting Antennas, by R. S. Tener, student. Social meeting, with refreshments and smoker after program. February 20. Attendance 28.

Case School of Applied Science

Business Meeting. Election of the following officers for year 1929-1930: President, R. B. McIntosh; Vice-President, T. S. Hudson; Secretary, H. L. Brouse; Treasurer, V. S. Roddy; Safety Representative, K. G. Young. February 26. Attendance 37.

Clemson Agricultural College

Student Activities, by W. C. Snyder, student;

Engineering Achievements of 1928, by J. B. Bevill, student;

Current Events, by S. B. Harper, student, and

Water Power Development in South Carolina, by Prof. S. R. Rhodes, Counselor. February 21. Attendance 17.

Cooper Union

High-Frequency Phenomena, by C. H. Coles, 5th-year Night School student. Demonstrations. February 20. Attendance 80.

Film—"The Single Ridge." A representative of the Okonite Company was present to answer questions. March 6. Attendance 33.

Visit to Walker Street Building of A. T. & T. Co. March 10. Attendance 30.

University of Detroit

Operation of Automatic Sub-Stations, by J. E. Theriault, Instructor of Operators School, Detroit Edison Co. Movies: "The Single Ridge" and "Driving the Longest Railroad Tunnel in the Western Hemisphere." Luncheon preceded meeting. February 5. Attendance 70.

The Sonnic System, or Transmission of Power by Vibrations, by Dr. Leucutia, Harper Hospital;

Growth of the S. A. E. in Detroit, by B. L. Lemmon. Chairman of Detroit Sdction, and

Automotive and Specialized Engineering, by O. T. Kreusser, Director, General Motors Proving Grounds. Joint meeting with Engineering Society of the University. March 4. Attendance 245.

Duke University

Ship Electrification, by R. A. Cassidy, student, and

Power Involved in Voice Reception, by Prof. W. J. Seeley, Counselor. Moving picture, "Electrical Measuring Instruments" Business session. March 1. Attendance 22.

University of Florida

Building a Radio Station, based upon problems encountered in erecting the University station WRUF, by Dr. J. R. Benton, Dean of the Engineering College. March 11. Attendance 27.

Georgia School of Technology

Business Meeting. Prof. T. W. Fitzgerald, Head of the Electrical Engineering Dept., nominated for appointment as Counselor to succeed Prof. Hannaford, who resigned from the faculty. February 19. Attendance 27.

Outstanding Developments in the Electrical Industry in 1928, by John Liston, General Electric Co. Slides. February 27. Attendance 48.

State University of Iowa

Carrier Current Telephony, by Mr. Baumgartner, student, and

Street Railways, by Mr. Finch, student. November 28. Attendance 36.

Oil-Electric Locomotives, by Mr. Hemphill, student, and

Boulder Dam, by Mr. Hatch, student. December 5. Attendance 33.

High-Voltage D-C. Generators, by Mr. Hicklin, student, and

Sound Moving Pictures, by Mr. Holmes, student. January 16. Attendance 29.

Business Meeting. January 30. Attendance 28.

Reconstruction of Two 17,000 Kv-Ampere Generators, by Mr. Johnston, student, and

Phillipine Islands, by Mr. Mariano, student. February 13. Attendance 31.

Flashing of Synchronous Converters, by Mr. Mathis, student, and

Niagara Power Plant, by Mr. Martinez, student. February 27. Attendance 32.

University of Kansas

What Makes a Successful Engineer, by R. O. Shepp, student, and

Photoelectric Cells, by Norvel Douglas, student. Business session. February 21. Attendance 27.

University of Kentucky

Prof. W. E. Freeman, Counselor, explained the motion picture films: "Gas-Electric Buses" and "Largest Single-Unit Electric Locomotive." February 19. Attendance 40.

Lehigh University

Welding, by Charles Schneck, Production Engineer, Bethlehem Steel Co.;

Welding Research Work at Lehigh, by Prof. C. D. Jensen, and

Training and Testing Welders, by H. J. Bowles, Welding Supervisor of Saucon Division, Bethlehem Steel Co. Joint meeting with Lehigh Valley Section and Engineers Club of Lehigh Valley, preceded by a dinner. Number of after-dinner speeches by prominent engineers and professors. February 23. Attendance 175.

Lewis Institute

Joint meeting with Armour Institute of Technology Branch. (See report under Armour Institute). February 14. Attendance 65.

University of Louisville

Neon Signs, by G. M. Miller, Supt. of Distribution, Louisville Gas and Electric Co. Two-reel film "The Edison Storage Battery" shown by N. C. Pearcy, Louisville Gas & Elec. Co., Secy., Louisville Section, A. I. E. E. Chairman Evans urged that a number of Branch members submit papers. Refreshments were served. February 15. Attendance 20.

University of Maine

A Summer with General Electric Co., by E. F. Cooper, '29. Films—"Power Transformers" and "Beyond the Microscope." March 7. Attendance 15.

Marquette University

The Transmission of Radio Currents on Telephone Cables, by John Gibbons, Wisconsin Telephone Co. Slides and instruments. Business session. November 1. Attendance 33.

Hardships Endured in the Building of the First Transcontinental Railroad, by T. C. Hatten, Chief Engr., Metropolitan Sewage Commission. A mock trial was held in which A. Jackson, J. Higgins, W. Clancy, G. Morrison and R. Eiff took part. December 13. Attendance 65.

Correction of Radio Interference Caused by Electric Company Equipment, by T. Bailey. Business session. January 17. Attendance 22.

Michigan State College

Business Meeting. November 12.

Business Meeting. January 24.

University of Michigan

Talking Movies, by Dr. J. O. Perrine, American Tel. & Tel. Co. Illustrated. Two reels of talking movies shown. February 27. Attendance 450.

University of Minnesota

Legal Problems Arising in Engineering, by A. W. Groth, Minneapolis Attorney. February 14. Attendance 150.

University of Missouri

Scientific Curiosity, by A. K. Bushman, General Electric Co. Films—"Beyond the Microscope" and "Thomas A. Edison." February 19. Attendance 41.

Montana State College

Counting Atoms and Electrons, by Dr. L. F. Curtiss, from *Scientific Monthly* for November 1928. Reader, F. Johnson, student;

Magnet Defies Gravitation, from *Science & Invention*, March. Reader, Eitaro Etow, student, and

Insulation. The Opportunity for Research, by J. B. Whitehead, from A. I. E. E. JOURNAL, January 1929. Reader, R. H. Crumley, student. February 14. Attendance 75.

Forces on Magnetically Shielded Conductors, by J. H. Morecroft, and Alva Turner, from A. I. E. E., JOURNAL, January 1929. Reader, Homer A. Morton, student;

The Milwaukee Electric Passenger Locomotives, by Lowell Kurtz, student, and

Electrical Timing on Race Tracks, from January *Motor World*. Reader, Bruce Mull, student. February 21. Attendance 80.

Graphic Instruments Search Out Power Faults, by R. S. Wertheim and W. D. Riggs, from *Power Magazine*, February 16, 1929. Reader, A. W. Greiner, student;

Uses of Radio as an Aid to Air Navigation, by J. H. Dellinger, from A. I. E. E. JOURNAL, February 1929. Reader, E. F. Sauke, student, and

"Shotgun" Fuse Solves High-Tension Problems, by J. P. Medlin, from *Electrical World*, February 23, 1929. Reader, Fred Sugiura, Student. February 28. Attendance 79.

University of Nebraska

Inverted Speech, Delayed Speech, Mechanical Larynx and Synthetic Lung, by S. P. Grace, Asst. Vice-President, Bell Telephone Laboratories, Inc. February 14. Attendance 35.

Temperature Measuring Devices, by Dan McQuaid, Taylor Instrument Co. Joint meeting with A. S. C. E. Chapter and A. S. M. E. Branch. February 27. Attendance 100.

Bakelite—A Research of Synthesis, by R. C. Shney, Research Engr., Bakelite Corp. Illustrated. Banquet, sponsored by Lincoln Engineers Club. March 6. Attendance 65.

Newark College of Engineering

The Interconnection of Power Systems, by C. S. Gray, student, and

The Clark Thread Company's Power Plant, by L. M. Klenk, student. February 25. Attendance 24.

Telephone Central Office Power Plant Equipment, by E. J. Lott, student, and

Interconnections of Power Systems, by C. M. Stuehler, student. Business session. Inspection trips were discussed and the treasurer's report was read and accepted. Pictures of the ship *California* were shown. March 4. Attendance 24.

University of New Hampshire

The Magnetic Blow-Out, by J. W. Theall, student, and

Measurement of High-Voltage Disturbances, by J. F. Tinker, student. February 9. Attendance 30.

The Electric Phonograph, by J. C. Terry, student;

Radio as an Aid to Air Navigation, by A. K. Whitcomb, student, and

Thermal Overload Protection for A. C. Motors, by G. W. Withington, student. February 23. Attendance 27.

My Summer's Work—and the Apprentice System of the N. Y., N. H. & H. R. R., by W. R. Wood, student;

The Shaded Magnetic Field, by K. E. Wheeler, student, and

Causes of Irregular Wave Form in an Alternator, by R. W. Adams, student. March 2. Attendance 30.

College of the City of New York

Business meeting. February 21. Attendance 18.

The Method of Standardizing Gasoline for Automobiles with Tetra-Ethyl Lead, by Dr. Graham Edgar, Ethyl Gasoline Corp. Joint meeting with A. S. M. E. and A. I. Ch. E. Branches. February 28. Attendance 70.

Inspection trip to Lehn & Fink, Inc., Bloomfield, N. J. March 8. Attendance 27.

New York University

The Gas-Electric Bus, by George Berggren, student, and

The Effects of Electrolysis on Gas and Water Mains, by Frank Goss, student. December 10. Attendance 23.

The Arc Light, by Harold Torgersen, student, and

Spot Welding and Its Application, by C. Iserman, student. January 10. Attendance 18.

The Gyrocompass, by Mr. Streicher, student;

The Evils of a Low-Power Factor, by Mr. Schmidt, student, and

Transmission Structures, by Mr. Meagher, student. February 13. Attendance 19.

The Fundamental Principles of Television, by Mario Banfi, student;

The Methods Used to Safeguard the Millions of Passengers on the Railroads of the United States, by Kenneth Estler, student, and

An Economic Consideration of the Use of Electricity for Cooking Purposes, by W. Conron, student. February 27. Attendance 21.

University of North Carolina

Work with Duke Power Company, by W. B. White, student, and

Work with the Tidewater Power Company and the Testing of House Meters, by E. R. Davis, student. The following officers elected: President, W. B. Sharp; Vice-President, H. J. Hines, Jr.; Secretary, E. T. Gross, Jr.; Treasurer, W. B. Massenburg (re-elected). February 14. Attendance 18.

The History of Radio, by H. W. Arlin, Personnel Director, Mansfield Plant, Westinghouse Electric & Mfg. Co., and

Student Engineers with General Electric Co., by H. J. Wheeler, February 28. Attendance 30.

University of North Dakota

Modern Electrical Railways, by Burke Bair, student, and

The Business Side of Engineering, by Gustave Glass, student. December 13. Attendance 20.

Still-film "Air Port Lighting." February 7. Attendance 20.

Talking Movies, by Charles Brietweiser, student, and

Magnetically Shielded Conductors, by Charles Powell, student. Discussion of plans for Engineers Day. February 14. Attendance 22.

Construction Problems, by C. H. Van Petten, Construction Engr., Demers Bridge. February 20. Attendance 51.

Northeastern University

Inspection trip to Simplex Wire and Cable Company. Following the tour several high-tension tests were exhibited in the electrical research laboratory. February 16. Attendance 62.

Ohio Northern University

High-Speed Circuit Breakers, by R. F. Rice, President. Plans were completed for holding the Engineers Week. February 7. Attendance 18.

Ohio State University

Value of Public Speaking to the Engineer, by R. E. Knox, student, and

Electric Railways, by E. C. Gunn, General Electric Co. Illustrated. February 7. Attendance 45.

Cosmic Rays, by H. F. Blake, student. Prof. F. C. Caldwell was presented with a cup as a token of appreciation of the work he has done as Counselor of the Branch. Motion picture—"The Single Ridge." Talk was given by C. S. Coler, Manager, Educational Dept., Westinghouse Electric & Mfg. Co. Election of officers. February 28. Attendance 55.

Oklahoma A. & M. College

Motion pictures—"Power Transformers" and "I See You Calling Me." February 13. Attendance 12.

University of Oklahoma

State Line Power Plant, by R. W. Coursey, student;

Western Electric Plant, by LeRoy Moffett, student;

Radio Station WENR, by E. P. Shultz, student;

Chicago Municipal Air Port, by Bill Woods, student, and

Keokuk Power Plant, by Charles Ittner, student. February 14. Attendance 27.

Business meeting. March 7. Attendance 20.

Oregon State College

Present Day Vitaphone and Movietone Equipment, by A. L. Albert, Instructor in Elec. Engg. February 11. Attendance 66.

Inspection of Vitaphone and Movietone Equipment at the Whiteside Theatre. February 13. Attendance 63.

Film—"Power Transformers." Explanatory comments were made by E. C. Starr, Instructor in Elec. Engg. February 18. Attendance 62.

Safety Engineering, by John B. Fisken, Consulting Engr., Washington Water Power Co. G. E. Quinan, Vice-President, District No. 9, spoke on the Institute and related activities. February 19. Attendance 38.

Pennsylvania State College

Two Summers in Alaska, by B. L. Robertson, Elec. Engg. Dept. Prof. L. A. Doggett discussed the Regional Convention to be held in Cincinnati, March 20-23. February 13. Attendance 75.

University of Pennsylvania

Opportunities of the Engineer in Industry, by H. D. James, Consulting Control Engr., Westinghouse Electric & Mfg. Co. A few remarks were also made by A. M. Dudley, Engg. Supervisor of Development of the same company. February 13. Attendance 36.

Fifth Annual Banquet. Talks were given by the following: W. R. Whitney, Director of Research, General Electric Co.; W. F. G. Swann, Director of the Bartol Laboratory of Franklin Institute, and Harold Pender, Dean of the Moore School of Electrical Engg. February 20. Attendance 100.

Purdue University

The Photoelectric Cell in Communication, by Dr. J. O. Perrine, American Tel. & Tel. Co. Illustrated with slides and talking pictures. February 25. Attendance 450.

Rhode Island State College

Electric Tug Boats, by Harold Gerlack, student, and

S. S. California, by Joseph Disano, student. February 15. Attendance 26.

Smoker. Prof. William Anderson and Dean R. W. Wales spoke on the advantages of participation in the activities of the A. I. E. E. February 20. Attendance 19.

Radio Communication on Trains, by Nicholas Abbenante, student, and

Television, by Edward Aceton, student. March 1. Attendance 16.

Rose Polytechnic Institute

Light and Vision, by W. E. Dodson, student, and

Lighting and Its Relation to the Industries, by F. O. Andrews, student. Slides. February 21. Attendance 37.

Heaviside's Method of Mathematical Analysis, by Prof. H. R. Mason. March 7. Attendance 37.

Rutgers University

Surge Impulse Breakdown of Air, by W. Dalton, '29, and

A-C. Filter Circuits, by E. Wilson, '29, February 5. Attendance 22.

High-Speed Circuit Breakers in Electric Railways, by W. Breazeale, '29, and

Ground Detection in Isolated D. C. and A. C. Circuits, by Mr. Wolfe, '29. February 12. Attendance 22.

Deion Circuit Breakers, by Mr. Sherbo, '29, and

Recent Improvements of Turbo-Generators, by Mr. Walton, '29. February 19. Attendance 22.

South Dakota State School of Mines

Work of the Telephone Laboratories, by G. E. Bickley, Division Personnel Supervisor, N. W. Bell Tel. Co. February 25. Attendance 40.

University of South Dakota

Amateur Photography, by Orla Bendixen. February 11. Attendance 12.

Business Meeting. The following officers were elected: Chairman, Enar Johnson; Vice-Chairman, H. Scholes; Secretary, E. E. Lovejoy; Safety Council Chairman, P. Miller. Committees were also appointed as follows: Lodging—Mr. Dickinson; Inspection Trip—Mr. Crosby, and Entertainment—Mr. Johnson. February 25. Attendance 14.

Stanford University

Automatic Electric Welding, by Mr. Owens, General Electric Co. Illustrated with motion picture. Mr. Brown of San Francisco exhibited some slides showing the welding problems encountered in a job shop. Joint meeting with A. S. M. E. February 7. Attendance 45.

Telephoto, by L. A. Gary, Pacific Telephone & Telegraph Co. Illustrated.

Broadcasting Equipment, by C. S. Smith, Jr., of the same Company. Illustrated. February 27. Attendance 100.

Inspection of the telephoto and broadcasting equipment in the Grant Avenue Exchange of the Telephone Company in San Francisco. March 2. Attendance 23.

Stevens Institute of Technology

Smoker. Talks on "The Smoke Nuisance" were given by H. N. Davis, President, Stevens Institute, Dr. Darlington and Samuel Frontz. Demonstration of photographic apparatus, electrically operated. Film—"Promotion of the Engineering Congress at Tokio, Japan." Joint with A. S. M. E. March 6. Attendance 70.

Texas A. & M. College

Reproduction of Sound and Scene, by J. L. Gatlin, student. The following pictures were shown: "Magic of Communication."

"Western Electric," "The Telephone Repeater," "The Electric Transmission of Speech." H. W. Whitney, with the assistance of C. S. Robinson, students, demonstrated the effect of cutting out various frequencies of voice and music by filters. February 22. Attendance 86.

University of Texas

Film—"Power Transformers." Plans were discussed for an inspection trip to the power plant of the Texas Power and Light Co. February 14. Attendance 23.

Electrolysis in Power Distribution Systems, by Professor Ramsey. Plans for the Regional Meeting to be held in Dallas, May 7-9, discussed. February 28. Attendance 18.

University of Utah

Movietone, by Lorin Moore, student. February 12. Attendance 14.

University of Vermont

The Conowingo Development, by D. S. Chamberlain, '29. February 12. Attendance 15.

Opportunities for Employment in The Bell System, by C. E. Brown, '28. A combined report on "Theory, Operation, and Testing of the Deion Circuit Breaker" was given by A. E. Merrill, '30, R. A. Dailey, '30, and F. E. Beckley, '30. February 27. Attendance 18.

Washington State College

Westinghouse East Pittsburgh Works, by Prof. H. F. Lickey. Program and Membership Committees appointed. February 13. Attendance 20.

University of Washington

Sidelights on Einstein's Theory of Relativity, by J. E. Maynard, student. February 1. Attendance 19.

A Few More Waves, by L. A. Meacham, student. Illustrated by means of a violin string. February 8. Attendance 18.

The Life of Michael Faraday, by J. A. Renhard, student. February 15. Attendance 13.

Business Meeting. Discussion of plans for joint meeting with the Seattle Section. March 8. Attendance 12.

West Virginia University

Making the Small Turbine Safe, by C. A. Bowers, student; *Electrification of French Railways*, by G. D. Burner, student; *Automatic Brake Control for Super-Synchronous Motors*, by G. H. Hollis, student; *Radio Aid to Air Navigation*, by W. S. Bosely, student; *Frequency Control for Broadcasting*, by C. B. Seibert, student, and *Standardization of Electrical Measuring Instruments*, by J. R. Nottingham, student. February 18. Attendance 18.

Elevator Motors, by O. R. Allen, student; *Electric Trolley in Foundry*, by G. C. Barnes, student; *Shotgun Fuse for High-Tension Service*, by S. N. Gidding, student; *Influence of Atmospheric Conditions on High-Tension Insulators*, by E. M. Hansford, student, and *Electric Marine Equipment*, by J. Kayuha, student. February 25. Attendance 20.

The Influence of Glaze on Insulator Strength, by R. H. Pell, student; *The Tendency in the Design of Portable Instruments*, by W. H. Ross, student; *The Great Northern Railway Electrification across the Cascade Mountains*, by W. C. Warman, student; *Radio Telephone Used on Railways*, by Frank Watson, student, and *Parasites of the Electric Contracting Industry*, by V. O. Whitman, student. March 4. Attendance 19.

Worcester Polytechnic Institute

The Underlying Principles of Television, by Dr. J. O. Perrine, American Tel. & Tel. Co. Illustrated. February 13. Attendance 130.

Westinghouse Production Methods, by H. C. Bates, '29;

Laying Out Power Lines, by A. C. Halt, '29, and

Experiences with N. Y. Edison Company, by C. L. Robinson, '29. Election of officers. March 5. Attendance 35.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, Feb. 1-28, 1929

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

AEOLUS; OR, THE FUTURE OF THE FLYING MACHINE.

By Oliver Stewart. N. Y., E. P. Dutton & Co., 1928. 91 pp., 6 x 4 in., cloth. $1.00.

A brief discussion of the future of civil and military flying machines and of the airship. The author has decided views on many disputed points, and his little essay will interest every one connected with aviation.

AEROPLANES, SEAPLANES, AND AERO ENGINES.

By Capt. P. H. Sumner. Lond., Crosby Lockwood & Son, 1929. (Science of Flight, v. 2). 292 pp., illus., 9 x 6 in., cloth. 25s.

After a historical introduction, this book discusses the principles of aerodynamics, the airscrew, types of engines, the general design and construction of aircraft, rigging, modern types of aeroplanes and seaplanes, and aeronautical instruments. The book is descriptive rather than theoretical, but contains a large amount of information on current craft, and is profusely illustrated.

Bauelemente der Feinmechanik.

By O. Richter. Berlin, V. D. I. Verlag, 1929. 576 pp., illus., tables, 10 x 7 in., bound. 29.-r. m.

This volume is a first attempt to provide the instrument maker with a systematic presentation of the elements of instruments, similar to the well-known books on the elements of machines. It treats successively of the materials used, connections, bearings, driving mechanisms and regulating devices, giving descriptions of a great variety of practical methods, with the necessary data for the designer.

The book will be valuable to manufacturers and designers of typewriters, sewing machines, phonographs, meters, optical instruments and similar apparatus.

Bibliography of Metallic Corrosion comprising references to papers on ferrous and non-ferrous corrosion (including methods of protection) published up to the end of 1927. Greatly enlarged from a bibliography prepared for the British Non-ferrous Metals Research Association and privately issued to its members.

By W. H. J. Vernon. Lond., Edward Arnold & Co., [N. Y., Longmans Green & Co.] 1928. 341 pp., 9 x 6 in., cloth. $8.40.

This bibliography is the work of a skilled investigator of corrosion, who has brought to its compilation and annotation unusual qualifications for the task. The result is a work that will prove indispensable to practically every one in the metal industries or interested in the preservation of metal structures.

The bibliography is arranged chronologically under four topics; the types of corrosion and the factors influencing it, the corroding medium, the metal or article corroded, and protective methods. Numerous annotations and introductory notes are given, and there are sufficient cross references. Over 3800 entries are included.

Bridge and Structural Engineers' Handbook.

By Adam Hunter. 2nd edition. Lond., E. & F. N. Spon; N. Y., Zpon & Chamberlain, 1928. 345 pp., diagrs., tables, 9 x 5 in., cloth. 21s.

This desk reference book, popularly known as "Arrol's handbook," embodies the practise of Sir William Arrol and Company, Ltd., of Glasgow. The scope of the work is indicated by the title. It gives the formulas and data commonly needed by the designer in the form most convenient for office use, and embodies the results of long practical experience in construction.

Bureau of Chemistry and Soils.

By Gustavus A. Weber. Balt., Johns Hopkins Press, 1928. (Institute for government research. Service monographs . . . no. 52) 218 pp., 9 x 6 in., cloth. $1.50.

A careful account of the history of the Bureau of Chemistry, of the work that it does and of the organization of its forces. The book is entirely descriptive and is based on official documents.

Comprehensive Treatise on Inorganic and Theoretical Chemistry, v. 9.

By J. W. Mellor. Lond., & N. Y., Longmans, Green & Co., 1929. 967 pp., diagrs., 10 x 6 in., cloth. $20.00.

The ninth volume of Dr. Mellor's great work is devoted to arsenic, antimony, bismuth, vanadium, columbian, and tantalum. The plan and high standard of the preceding volumes are maintained. For each metal, the history, occurrence, extraction, and properties are discussed, and its important compounds are described in some detail. No other work in English comes so near to filling all the ordinary needs of the chemist, nor does any other contain such exhaustive bibliographies for further information. It is indispensable as a reference work.

Electrical Engineering Problems. Pt. 2; A-c. circuits and Apparatus.

By John G. Pertsch, Jr. N. Y., McGraw-Hill Book Co., 1929. 105 pp., diagrs., 9 x 6 in., cloth. $2.00.

A companion to the author's volume of problems on direct-current circuits. The book contains a classified series of problems, typifying actual practise, intended to give the student practise in application of the fundamentals of the subject.

Engineering English.

By John Hubert Scott. N. Y., John Wiley & Sons, 1928. 321 pp., 9 x 6 in., cloth. $2.75.

This is an interesting and unusual book. Professor Scott presents a course in composition, covering two semesters, which is carefully planed to train the student to express his ideas accurately and correctly, in a pleasing manner. The presentation of the material is unusually definite and complete, due attention is given to matters of mechanical form, and much general information on the correct use of English is included. The book will be helpful to every writer.

An Etymological Dictionary of Chemistry, & Mineralogy.

By Dorothy & Kenneth C. Bailey. Lond., Edward Arnold & Co.; N. Y., Longmans, Green & Co., 1929. 308 pp., 9 x 6 in., cloth. $10.00.

The reader who is curious about such things will find here the derivation of chemical and mineralogical names that have been current in the literature of the period beginning with the middle of the nineteenth century. Each word is defined briefly, and the authority for the derivation given.

Evolutions of the Igneous Rocks.

By N. L. Bowen. Princeton, Princeton University Press, 1928. 334 pp., diagrs., tables, 9 x 6 in., cloth. $5.00.

Dr. Bowen's book is an attempt to interpret the outstanding facts of igneous-rock series as the result of fractional crystallization. He collects the facts that have been determined by the laboratory investigations of silica melts and shows how thay can be made to explain the derivation of the igneous rocks. The book is based on lectures given to advanced students of geology at Princeton, but presents an expanded view of the topic.

Exhaust Steam Engineering.

By Charles S. Darling. N. Y., John Wiley & Sons, 1929. 431 pp., illus., diagrs., tables, 9 x 6 in., cloth. $7.50.

An extended presentation of methods for utilizing waste heat by back-pressure engines, exhaust-steam turbines, steam accumulators, and distribution systems. The author writes from the point of view of the user rather than from that of the manufacturer. His aim is to cover the problems associated with the choice of machinery and the disposition of plant in a manner that will enable the owner to ascertain that he is utilizing his fuel to the best advantage.

History of Physics.

By Florian Cajori. Revised and enlarged ed. N. Y., Macmillan Co., 1929. 424 pp., illus., 8 x 5 in., cloth. $3.50.

Traces the development of physics from the beginning of history to the present day and presents a clear picture of the way in which current views have evolved and of the noted physicists of all ages. The new edition has been revised and extended to include recent discoveries.

Mathematical Tables & Formulas.

By Percey F. Smith and William Raymond Longley. N. Y., John Wiley & Sons, 1929. 66 pp., 8 x 5 in., fabriboid. $1.60.

A collection of the tables and formulas most used in solving the numerical problems given in college courses in trigonometry, analytic geometry, calculus, and mechanics.

Modern "Divining Rods."

By R. J. Santochi. 2nd edition. Glen Ellyn, Ill., The Author, 1928. 80 pp., illus., 9 x 6 in., paper. $2.00.

A curious collection of notes on useful and worthless devices for locating ore bodies, hidden metals, etc.

Organometallic Compounds, Pt. 1; Derivatives of the Elements of Groups I to IV.

By Archibald Edwin Goddard and Dorothy Goddard. (Text-Book of Inorganic Chemistry, v. 11; edited by J. Newton Friend) London, Charles Griffin & Co.; Phila., J. B. Lippincott Co., 1928, 418 pp., tables, 9 x 6 in., cloth. $14.00.

In this, the first portion of the final volume of this textbook, we have an extensive account of the organometallic compounds of groups 1 to 4 of the Periodic classification. Approximately 2300 compounds are described, and detailed methods for preparing all for preparing all key compounds are given. Ample references are given to sources of information that supplements the concise accounts of the text. The book treats of a class of compounds concerning which few monographs exist.

Precis de Construction, Calcul et Essais des Avions et Hydravions.

By J. Guillemin. Paris, Gauthier-Villars et cie., 1929. 442 pp., illus., tables, 10 x 7 in., paper. 100 fr.

A handbook for designers and builders, which gives concisely a great amount of data in practical form.

The author first treats of materials, describing their properties, uses and the standards of use. The forms of airplanes, their construction and the construction of their parts are then treated, after which the design of aircraft is treated in detail. Finally, methods of testing are given.

DER QUECKSILBERDAMPF-GLEICHRICHTER, v. 2; KONSTRUKTIVE GRUNDLAGEN.

By Kurt E. Müller-Lübeck. Berlin, Julius Springer, 1929. 350 pp., illus., diagrs., 9 x 6 in., bound. 42.-r. m.

Having considered the theory of mercury arc rectifiers very fully in his first volume, Mr. Mueller devotes the second to their construction. He first discusses the principles of design, giving chapters on voltage characteristics, wave characteristics, power characteristics, and the short-circuit current, and following these with a discussion of design itself. Following this he takes up questions of construction and of the erection of rectifier installations. The final chapter is a description of the great rectifying station of the Berlin railroads.

THE RADIO INDUSTRY; the story of its development as told by leaders of the Industry.

Chic., & N. Y., A. W. Shaw Co., 1928. 330 pp., illus., 9 x 6 in., cloth. $5.00.

The eleven lectures here collected were delivered at the Harvard Graduate School of Business Administration during 1927 and 1928. They include a history of radio development, by David Sarnoff, an account of radio in the World War and of the organization of an American owned transoceanic service, by General Harbord, radio telephony by Doctor Jewitt, the law of the air by Judge Davis, the early history of broadcasting by H. P. Davis, the development of national broadcasting by M. H. Aylesworth, radio merchandising, by J. L. Ray, radio advertising by Pierre Boucheron, and industrial applications of radio by H. C. Weber.

THE ROLE OF SCIENTIFIC SOCIETIES IN THE SEVENTEENTH CENTURY.

By Martha Ornstein. Chicago, University of Chicago Press, 1928. 308 pp., 9 x 6 in., bound. $3.00.

It was during the seventeenth century that the experimental method of studying science was introduced, and the change was due, not to the universities, but rather to the work of independent workers banded together in scientific societies. The present book is intended to show how science advanced during that century, what part was played by individual scientists, and what was done by societies in Italy, England, France, and Germany. The beginning of the scientific journals are traced, and the attitude of the universities toward the experimental sciences is discussed.

SALTS, ACIDS AND BASES; Electrolytes; Stereochemistry.

By Paul Walden. N. Y., McGraw-Hill Book Co., 1929. (George Fisher Baker Non-resident lectureship in chemistry) 397 pp., port., tables, 9 x 6 in., cloth. $4.00.

These lectures were delivered at Cornell University in 1927-28. They deal with the three branches of science in which Dr. Walden has been especially interested; the history of chemistry, electrochemistry and stereochemistry.

An introductory lecture on the lessons that modern chemistry can learn from alchemy is followed by lectures on salts, acids and bases, on electrolytes and non-electrolytes, on the electrical conductivity of non-aqeous solutions and on stereochemistry and optical inversion. The historical development is emphasized in each case, in an interesting way.

SOURCE BOOK IN ASTRONOMY.

By Harlow Shapley and Helen E. Howarth. N. Y., McGraw-Hill Book Co., 1929. (Source books in the history of the sciences). 412 pp., illus., ports., 9 x 6 in., cloth. $4.00.

The contributions of great workers of the past in science are often inaccessible to most students, and as a result his knowledge of their work is based on the secondary accounts given in textbooks. The present series, of which this is the first volume, is intended to remove the difficulty by providing, in convenient form, the most significant passages from the works of the most important sciences during the last three or four centuries. The series is endorsed by a number of the leading scientific societies.

The volume on astronomy contains excerpts from the work of sixty men, starting with Copernicus and ending with G. H. Darwin. All contributions are given in English.

STAGE LIGHTING.

By Theodore Fuchs, Bost., Little, Brown & Co., 1929. 500 pp., illus., 10 x 7 in., cloth. $10.00. (Gift of author).

This work should give great satisfaction to every one interested in stage lighting, whether he be a professional play producer, or amateur, or an illuminating engineer. The functions of stage lighting and the methods of producing desired effects are discussed fully, and in addition there is detailed, sound information upon the electrical equipment in use and the method of controlling it. Attention is paid to the needs of the amateur, by providing directions for designing and building equipment suited to his resources. The subject is treated with great clearness and the book is unusually comprehensive in scope.

STEAM, AIR, AND GAS POWER.

By William H. Severns and Howard E. Degler. N. Y., John Wiley & Sons, 1929. 425 pp., illus., tables, 9 x 6 in., cloth. $4.00.

An elementary text on heat engineering, for courses of limited duration. It aims to describe briefly and clearly typical and representative equipment, and to explain the theory of such machines and devices. The mathematical calculations involved are of the simplest order.

STEAM TURBINES.

By James Ambrose Moyer. 6th edition. N. Y., John Wiley & Sons, 1929. 557 pp., illus., plates, diagrs., tables, 9 x 6 in., cloth. $4.50.

In the new edition of this well-known text, special attention has been given to the calculations for the designing of steam turbines. New sections have been added upon the enlarged field of application of bleeder turbines, upon recent data on the variation of steam consumption with the age of turbines, upon various designs of packing, and upon new features in the design of large high-pressure turbines. An appendix contains the calculations for the design of a reaction steam turbine.

STRENGTH OF MATERIALS.

By Alfred P. Poorman. 2d edition. N. Y., McGraw-Hill Book Co., 1929. 343 pp., diagrs., tables, 9 x 6 in., cloth. $3.00.

This textbook by the Professor of Applied Mechanics at Purdue University is a companion to his "Applied Mechanics," and is intended for use by undergraduate students with a knowledge of physics, the calculus, and statics.

This new edition has additional matter on sudden and impact loads on beams, riveted joints, timber beams, and columns, and on safe stresses for timber.

VERSTARKERMESSTECHNIK; Instrumente und Methoden.

By Manfred von Ardenne. Berlin, Julius Springer, 1929. 235 pp., illus., diagrs., 10 x 7 in., paper. 22,50 r. m.

Discusses methods and apparatus for the accurate measurement of the efficiency of amplifiers. Methods are given in detail for measuring all the important characteristics, and the sources of possible error are pointed out. A bibliography is included.

VORLESUNGEN UBER DIFFERENTIAL-UND INTEGRALRECHNUNG, v. 2; Funktionen Mehrerer Veränderlicher.

By R. Courant. Berlin, Julius Springer, 1929. 360 pp., 9 x 6 in., cloth. 18,60 r. m.

The concluding volume of Professor Courant's textbook treats of functions with several variables. As in the first volume, his aim has been to present the principles and methods clearly and to emphasize their practical applications.

DER WARMEUBERGANG BEIM KONDENSIEREN VON HEISS UND SATTDAMPF.

By M. Jacob and S. Erk; also Die Verdampfungswärme des Wassers und das Spezifische Volumen von Sattdampf für Temperaturen bis 210 deg. C. By M. Jakob. (Forschungsarbeiten, heft 310) Berlin, V. D. I. verlag, 1928. 19 pp., diagrs., tables, 12 x 9 in., paper. 3.50 r. m.

Although steam is our most important technical conveyor of energy, but little is yet known about some of its properties, because of the difficulty of experimental investigation of them. This is true, for example of the process of condensation, which is so incompletely understood that it has been uncertain whether superheated or saturated steam is most effective in this case as a heat carrier. The first report in this pamphlet describes a study of the comparative values of the two, the conclusion being that they are equally efficient, if the steam condenses.

The second report is on a study of the heat of vaporization of water, and gives the results obtained between 30 deg. and 210 deg. cent.

WHAT ENGINEERS DO; an Outline of Construction.

By Walter D. Binger. N. Y., W. W. Norton & Co., 1928. 259 pp., illus., 8 x 5 in., cloth. $2.75.

Not only boys, but also many adults, will be interested in this popular account of the work of the civil engineer. The author, a practising engineer, tells how bridges and buildings, highways and railroads are built, how land is surveyed and mapped, how floods are controlled and water utilized. An unusually good attempt at popularization.

WIE TECHNIK DIR IM HAUSHALT HILFT.

By C. Säuberlich. Berlin, V. D. I. Verlag, 1928. 119 pp., illus., 8 x 6 in., paper. 4.80 r. m.

Explains the principles and construction of the technical appliances used in the household. Heating and ventilating apparatus, gas and electric cooking devices, washing, and ironing machines, refrigerators, lamps, and minor devices are described in simple language.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.

1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.

57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL ENGINEER, graduate, for electrical engineering department of school of technology beginning next September. Previous teaching experience not essential. Salary about $2700 for academic year. Advancement and permanency. Apply by letter giving full personal and professional particulars. Photograph desirable. Location, New York. X-7523.

ELECTRICAL ENGINEER, young, graduate, with one or two years' experience for high-voltage transmission investigation. Experience with Cathode-Ray Oscillograph desirable. Apply by letter. Location, Pennsylvania. X-7504.

ENGINEERS, who have had extensive practical experience in precision, electrical and physical measurements. Technically trained men who can show a definite aptitude for laboratory and development work and who can develop along engineering or executive lines, desired. Range of work covered is very broad. Apply only by letter. Location, Massachusetts. X-7537.

ELECTRICAL ENGINEER, to design line of small low-voltage motors. Must be thoroughly familiar with modern production testing and inspection methods. Apply by letter, stating salary expected. Location, Middle West. X-7376-R-386-C.

TECHNICAL GRADUATE, with experience in electrical laboratory on conventional electrical research and theory. Apply by letter. Location, New Jersey. X-7446.

ELECTRICAL ENGINEER. Graduate who has had five or six years' experience in designing power stations and high- and low-tension substations. Apply by letter. Location, New England. X-7223.

MECHANICAL ENGINEER, 28-35, thoroughly experienced in designing small automatic machinery, with college mechanical training and thorough shop experience. Opportunity. Apply by letter, state age, experience and education; also, minimum salary expected. Location Middle West. X-7447-C.

DISTRIBUTION ENGINEER, electrical engineer, with 4-6 years' experience for making distribution surveys on medium size public utility companies, making the necessary computations and preparing plans for the revamping and improving of such systems. Apply by letter. Location, New England. X-7266.

SALES ENGINEER, 1927 or 1928 graduate in electrical engineering for commercial side of manufacturing organization, traveling sales work. Opportunity. Location, Middle West. X-7662-C.

MEN AVAILABLE

ELECTRICAL SALES AND CONSTRUCTION ENGINEER, 31, desires connection with reliable company; graduate of two technical colleges with ten years' varied experience; 7½ years with largest electrical manufacturer; graduate student electrical engineering test course; experience in turbine engineering, switchboard; district office and resident agent sales; also, specialty merchandising. C-5618.

ELECTRICAL ENGINEERING GRADUATE, 27, single, good health, desires position with operating or public utilities company. Four years' experience in electrical service and repair work, and five years' business experience devoted largely to selling. Southern location preferred but not essential. C-4828.

ELECTRICAL ENGINEER, married, desires position as design, research or development engineer. Thorough practical experience in power station and transmission lines, in applying laboratory results to practical uses, trained to do systematic work and organizing; possesses sound theoretical knowledge in electromechanics and electrophysics. Speaks German and French. C-693.

COMBUSTION ENGINEER, with technical training and extensive experience in operating pulverized coal, oil and stoker fired plants, desires position where ability along such lines is required. Capable of operating boiler plants of any size or of designing same. Now Sales Engineer for large corporation but do not like sales work. A-5506.

ENGINEER, 28, single, electrical engineer also member of I. R. E. One year in testing laboratory; five years in radio manufacturing, including design, research and production of parts and complete receivers. Desires to associate with small manufacturer or distributor; might consider investment in proposition having merit. Location, New York City. B-5138.

MECHANICAL AND ELECTRICAL ENGINEER, 39, single; thorough engineering training; 15 years' experience in United States and abroad in research work and generation, distribution, utilization of electric energy in industry, mines, railroads. Economist. Executive ability. Speaks and writes English, German, and French. Location, immaterial. C-2327.

PROFESSOR OF ELECTRICAL ENGINEERING, with over 10 year's experience as head of Electrical Engineering Department in one of the largest engineering colleges and with additional experience in teaching, practical and administrative work, now in Mid West, desires position as teacher or as an educational director in an Eastern State. C-5609.

MEMBER OF THE BAR AND ELECTRICAL ENGINEER, desires position with responsible attorney, firm or corporation. C-5661.

ELECTRICAL, MECHANICAL ENGINEER, University graduate. Twelve years' experience in technical, commercial, production side of profession. Specialized in oil-circuit breakers, apparatus. Executive, inventive ability. Past two years in charge of engineering in well-known firm abroad. Resigning to return to U. S. Desires connection with progressive manufacturing company, public utility. Any location, preferably West or Middle West. C-5652.

ELECTRICAL ENGINEER AND DESIGNER, 31, B. S.; 8 years' experience with public utilities and engineering corporations covering design, specifications and inspection. Speaks German. Desires position as field engineer in New York City or vicinity. C-5473.

ELECTRICAL ENGINEER, 30, married, good personality and executive ability, with eight years' varied experience, including design, test maintenance and inspection power plant equipment. Two years supervising general test of electrical equipment, desires engineering position

with consulting engineer or industrial plant. C-151.

ELECTRICAL ENGINEER, 29, married. Graduate B. S. in E. E. With General Electric Company five years, including apprentice course. Experienced as cost estimator and sales correspondent. Desires connection with manufacturing concern. C-5678.

PLANNING ENGINEER, 33, married; 8 years' electric utility experience, including electrical system planning, preparation reports and improvement budgets, preparation of engineering contracts, supervision of engineering, coordination of activities of several departments, handling of work on account of municipal improvements and assistant to executive. B-9273.

ELECTRICAL ENGINEER, University graduate. Eight years' experience in design and manufacture of d-c. and a-c. motors and generators. At present in charge of complete electrical and mechanical development for midwest concern. Available upon reasonable notice. C-1801.

ELECTRICAL ENGINEER desires position doing research or development work. Thoroughly trained and competent meter engineer. Experienced in combustion and general laboratory and power plant testing. Has been successful along development lines; also, extensive public utility experience. C-5258.

ELECTRICAL ENGINEER, of extensive education and with wide experience in d-c. machine design. A specialist in economical proportioning. C-5701.

UNIVERSITY GRADUATE IN ELECTRICAL ENGINEERING, married, 30; two years' general experience and four years as instructor of electricity and drawing. Desires teaching position or position as a junior engineer. Now employed. B-7028.

ELECTRICAL ENGINEER, 40, married. Experienced in railway, automotive and building maintenance and repair; 14 years in mechanical department of large public utility as assistant superintendent of shops and master mechanic. Lower New England or northern New Jersey preferred. C-5632.

ELECTRICAL ENGINEER, graduated 1915, 35, with wide experience in construction, design and general engineering for power house, transmission, and distribution work; past three years engineer in Power Sales department of large utility corporation, specializing in steel mill applications. Desires connection as assistant electrical engineer with utility corporation or large manufacturing concern. C-5679.

ELECTRICAL ENGINEER, technical graduate, 43, single. General Electric Test, 7 years' experience in power layouts, substation designs, motor installations, wiring diagrams and kindred subjects for factory and industrial plants. Desires position along similar lines or as draftsman in charge of electrical squad. Now employed. Available 30 days. C-5681.

ELECTRICAL ENGINEER, graduate, 30, married, willing to travel. Has had two years' experience on General Electric Test, 1 year sales and contract service experience, three years in the electrical contracting business, and one year on valuation and appraisal work. Desires to enter sales, inspection or installation work. Will be available on short notice. B-9090.

ELECTRICAL ENGINEER, 31, 10 years' experience; two years complete wiring plans, specifications, engineering, correspondence, for light, power and signals on theatres, hotels, office buildings, loft buildings, clubs, etc; one year with electrical contractor on large buildings; desires permanent connection anywhere as designing engineer with architect, or estimating engineer with contractor. B-4217.

PROFESSOR OF ELECTRICAL ENGINEERING. Head of Department in a state university of high standing would consider a change of institution if opportunity and larger income would be available. Seven years' of practical experience as well as excellent liberal and technical training. Good teacher and organizer. Member of honorary and professional societies. C-5710.

ELECTRICAL ENGINEER, 26, married, 1925 graduate B. S. in E. E.; four years' experience public utility; power plant operating, meter department high- and low-voltage testing, rate schedule application; desirous of obtaining designing and construction engineering position with progressive firm. Location preferred, Atlantic Seaboard. C-5682.

ELECTRICAL ENGINEER, 34, married, graduate M. E., Cornell University. General Electric and Westinghouse Test Courses. Five years' experience in power plant construction and operation. Desires connection with industrial concern having its own power plant. Was in charge of 4000-Kw. industrial plant for three years. Available on short notice. C-5721.

MANAGER, experienced in every branch of electric public utility; engineering, construction, sales and management. Well versed on development of industrial power business, production of good service, satisfactory relations with customers and public. Technical graduate. B-7492.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

APPLICATIONS FOR TRANSFER

The Board of Examiners, at its meeting held March 6, 1929, recommended the following members of the Institute for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

DUER, J. V. B., Electrical Engineer, Pennsylvania Railroad, Altoona, Pa.
HAMILTON, GEORGE W., Vice-President in charge of Hydraulic and Electrical Engineering, Middle West Utilities Co., Chicago, Ill.
MOULTROP, IRVING E., Chief Engineer and Asst. Supt. of Construction Bureau, Edison Electric Illuminating Co., Boston, Mass.
SPALDING, SAMUEL A., Chief Engineer, Gibbs & Hill, Pennsylvania Station, N. Y.
SPOONER, THOMAS, Asst. Manager, Research Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
TAPSCOTT, RALPH H., Electrical Engineer, The New York Edison Co., New York, N. Y.

To Grade of Member

ANDERSON, GORDON R., Development Engineer, Fairbanks Morse & Co., Indianapolis, Ind.
ATHERTON, ALBERT, Engineering Assistant, Western Union Telegraph Co., New York.
BROWNELL, FRANK A., High Tension Division Chief, Public Service Elec. & Gas Co., Metuchen, N. J.
BULL, HEMPSTEAD S., Instructor in Elec. Engg., University of Michigan, Ann Arbor, Mich.
CARMICHAEL, ELWOOD T., Engg. Asst., Public Service Production Co., Newark, N. J.
COLEMAN, JAMES O'REILLY, Asst. Engr., National Electric Light Association, New York.
CUNNINGHAM, ALLAN, Manufacturer Marine Auxiliary Machinery, Seattle, Wash.
DAWSON, CECIL, Lecturer in Elec. Engg., Auckland University College, Auckland, N. Z.
DIEDERICH, P., Supt. of Light and Water Depts., City of Glendale, Glendale, Calif.
GEORGE, E. E., Supt. of Elec. Operation, Tennessee Elec. Pr. Co., Chattanooga, Tenn.
JONES, H. RUSSELL, Asst. Supt. and Elec. Engr., Celulosa Cubana, S. A., Tuinucu, Cuba.
LAUNDER, ARTHUR I., Division Traffic Engr., Pacific Tel. & Tel. Co., Seattle, Wash.
LEVY, DAVID H., Elec. Engr., Magnolia Petroleum Co., Dallas, Texas.
LYTLE, JAMES H., Consulting Engr., Staten Island Edison Corp., Staten Island, N. Y.
O'BRIEN, LAURENCE A., Telephone Systems Engg., Bell Telephone Labs., New York.
PULLEN, MYRICK W., Associate in Elec. Engg., Johns Hopkins University, Baltimore, Md.
PUTNAM, RALPH E. A., Transmission Engg., International Tel. & Tel. Co., New York.
QUARLES, DONALD A., Plant Systems Engr., Bell Telephone Labs., New York, N. Y.
RIDDLE, FRANK H., Director of Research, Champion Porcelain Co., Detroit, Michigan.
RIGGS, OLIVER L., Foreman-Underground Dept., Lynn Gas & Elec. Co., Lynn, Mass.
ROGERS, HURLEY T., Asst. Supt., Underground Construction, N. Y. & Queens Elec. Lt. & Pr. Co., Flushing, N. Y.
ROSEBRUGH, DAVID W., Asst. Rate Engr., Central Hudson Gas & Elec. Corp., Poughkeepsie, N. Y.
ST. CLAIR, HARRY P., Asst. to Elec. Engr., American Gas & Elec. Co., New York.
SCOTT, RALPH Y., Supervisor of Toll and Transmission Testing, New England Tel. & Tel. Co., Boston, Mass.
SELS, HOLLIS K., Asst. Transmission and Substation Engr., Public Service Elec. & Gas Co., Newark, N. J.
THERRELL, DANIEL M., Supervisory Dial Service and Radio, Southern Bell Tel. & Tel. Co., Atlanta, Ga.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before April 30, 1929.

Acock, G. W., General Electric Co., Schenectady, N. Y.
Adlington, E. R., Georgia Railway & Power Co., Atlanta, Ga.
Alford, E. L., Bell Tel. Laboratories, New York, N. Y.
Arnold, N., Columbia Engg. & Mgt. Corp., Cincinnati, Ohio
Axelsson, R. V., Byllesby Engineering & Management Corp., Chicago, Ill.
Ballou, H. P., (Member), Dept. of Power & Light, Sebring, Fla.
Bare, W. E, Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Behr, L., Leeds & Northrup Co., Philadelphia, Pa.
Blakeslee, T. M., Los Angeles Bureau of Pr. & Lt., Los Angeles, Calif.
Botts, M. P., Commonwealth Edison Co., Chicago, Ill.
Bowman, J. C., Public Service Electric & Gas Co., Newark, N. J.
Brady, R. A., General Electric Co., Philadelphia, Pa.
Brandenburg, F. E., Western Electric Co., Kearny, N. J.
Brandt, E. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Bruzina, R., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Buck, O. D., Texas Power Corp., Sequin, Tex.
Burgan, K. E., Ohio Bell Tel. Co., Akron, Ohio
Bush, F. P., Victor X-Ray Corp., Los Angeles, Calif.
Butcher, J. H., Michigan Bell Telephone Co., Detroit, Mich.
Cannizzo, M., (Member), Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Capodanno, R. T., Illinois Bell Telephone Co., River Forest, Ill.
Clingerman, R. J., General Electric Co., Erie, Pa.
Copeland, M. W., Luxortone Corp., Inc., Mt. Vernon, N. Y.
Cordier, N. A., Electric Storage Battery Co., New York, N. Y.
Cornelius, C. C., Kansas City Power & Light Co., Kansas City, Mo.
(Applicant for re-election.)
Correia, J. L., 602 West 137th St., New York, N. Y.
Coulehan, G. W., Allis-Chalmers Mfg. Co., Cincinnati, Ohio
Cowan, F. A., (Member), American Tel. & Tel. Co., New York, N. Y.
Coyle, H. F., New York Power & Light Corp., Albany, N. Y.
Curran, G. M., Electric Storage Battery Co., New York, N. Y.
D'Amato, N., 146 E. 129th St., New York, N. Y.
de la Cierva, J., General Electric Co., Schenectady, N. Y.
Dewey, G. W., N. J. Bell Telephone Co., Hackensack, N. J.
Dobson, L. C., Commonwealth Edison Co., Chicago, Ill.
Dowdell, J. R., Houston Lighting & Power Co., Houston, Tex.
Drake, H. N., Victor X-Ray Corp., Los Angeles, Calif.
DuChemin, N. M., General Electric Co., Lynn, Mass.
Dumont, D. P., Indiana General Service Co., Marion, Ind.
Eaglen, E. C., Oliver Iron & Steel Corp., Pittsburgh, Pa.
Edgerton, G. E., (Member), U. S. Army; Federal Power Commission, Washington, D. C.
Falkovich, O. C., C. M. Lovsted & Co., Inc., Seattle, Wash.
Fischer, V. C., Central Catholic High School, Toledo, Ohio
Foerster, J. A., (Member), City of Price Albert, Price Albert, Sask., Can.
Fox, W. S., Stevens & Wood, Jackson, Mich.
Frech, A. D., United Electric Lt. & Pr. Co., New York, N. Y.
Frederick, C. L., Bell Telephone Laboratories, New York, N. Y.
Frye, R. F., Westinghouse Elec. & Mfg. Co., Bridgeport, Conn.
Gallagher, F. J., Bronx Gas & Elec. Co., New York, N. Y.
Gottschau, C. M., Lanston Monotype Machine Co., Philadelphia, Pa.
Gulliksen, F. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Gustavsen, E., New York Central Railroad, New York, N. Y.
Haley, W. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Hart, L. C., (Member), Hi-Voltage Equipment Co., Cleveland, Ohio
Hazlehurst, C. M., Consulting Engineer, 712 Flat Iron Bldg., Asheville, N. C.
Hollis, I. H., Commonwealth Edison Co., Chicago, Ill.
Howland, E. W., Commonwealth Edison Co., Chicago, Ill.
Hubbard, C. J., Kansas City Power & Light Co., Kansas City, Mo.
Huber, G. H., Bell Telephone Laboratories, Inc., New York, N. Y.
Hunt, F. B., Nazareth Cement Co., Nazareth, Pa.
Ides, X. D., (Member), United Engineers & Constructors, Inc., Philadelphia, Pa.
Intrieri, N., New York Edison Co., New York, N. Y.
Ives, H. E., (Fellow), Bell Tel. Laboratories, Inc., New York, N. Y.
James, R. S., Interborough Rapid Transit Co., New York, N. Y.
Jennings, E. B., Southwestern Bell Tel. Co., Oklahoma City, Okla.
Johnson, W. H., Southeastern Engineering Co., Birmingham, Ala.
Jones, W. C., Toledo Edison Co., Toledo, Ohio
Kezele, M., Union Electric Lt. & Pr. Co., St. Louis, Mo.
Knowlton, J. J., Western Electric Co., Kearney, N. J.
Kraybill, V. H., Public Service Co. of No. Ill., Chicago, Ill.
Kyser, M. W., (Member), American Tel. & Tel. Co., Atlanta, Ga.
Laquidara, A. K., Plasterers Information Bureau, New York, N. Y.
Leazenby, A. L., Michigan Bell Telephone Co., Detroit, Mich.
Lee, Y. W., Mass. Institute of Technology, Boston, Mass.
Leppelman, L., Public Service Dept., Glendale, Calif.
Lowman, A. A., (Member), Northwestern Bell Telephone Co., Omaha, Nebr.
Matlock, L. F., Bureau of Reclamation, Pavillion, Wyo.
McCracken, E. G., Alfred Collyer Co., Toronto, Ont., Can.
McCurdy, R. G., (Member), Graybar Electric Co., Kansas City, Mo.
McDougal, W. L., Pullman Free School of Manual Training, Chicago, Ill.
McNeely, J. H., Clinton Electric Lt. & Pr. Co., Clinton, Conn.
McTaggart, F. E., West Penn Power Co., Pittsburgh, Pa.
Meath, P. L., Texas Construction Co., Houston, Tex.
Meytrott, C. W., Florida Power Corp. & Subsidiaries, St. Petersburg, Fla.
Moosbrugger, F. J., Public Service Co. of No. Ill., Evanston, Ill.
Muir, W., Cornell University, Ithaca, N. Y.
Mulligan, J. F., United Electric Light & Power Co., New York, N. Y.
Mullineaux, F., R. C. A. Photophone Inc., New York, N. Y.
Oldham, E. W., Commonwealth Edison Co., Chicago, Ill.
Paroonagian, L. A., Pennsylvania Railroad, Philadelphia, Pa.
Patton, E. P., Bronx Gas & Electric Co., New York, N. Y.
Person, A. W., Northern Nebraska Power Co., Crete, Nebr.
Petersen, A. H., Westchester Lighting Co., Mt. Vernon, N. Y.
Peterson, A. E., 6110 Rockridge Blvd., North, Oakland, Calif.
Phelps, J. E. B., (Member), Sarnia Hydro-Electric System, Sarnia, Ont., Can.
Phillips, C. A., Virginia Electric & Power Co., Roanoke Rapids, N. C.
Pierce, H. J., (Member), Northwestern Bell Telephone Co., Minneapolis, Minn.
Plummer, E. W., Buffalo General Electric Co., Buffalo, N. Y.
Powell, J. B., General Electric Co., New Haven, Conn.
Racer, T. J., Pacific Tel. & Tel. Co., Stockton, Calif.
Regniere, J. A., Shawinigan Water & Power Co., St. Narcisse, Que., Can.
Rietow, L. A., Pacific Electric Mfg. Corp., San Francisco, Calif.
Rommel, E. J., Toledo Edison Co., Toledo, Ohio
Ross, C. W., Roessler & Hasslacher Chemical Co., Niagara Falls, N. Y.
Ross, L. E., Niagara Falls Power Co., Niagara Falls, N. Y.
Rossiter, H. A., Electric Storage Battery Co., New York, N. Y.
Sammer, B. N., Union Oil Co., Los Angeles, Calif.
Sawford, H. S., American Tel. & Tel. Co., New York, N. Y.
Secrest, W. J., Firestone Tire & Rubber Co., Akron, Ohio
Sheldon, E. E., (Member), Utilities Engineering Co., Inc., Albany, N. Y.
Shermund, R. C., Federal Telegraph Co., Palo Alto, Calif.
Simpson, H. G., Canada Northern Power Corp., Ltd., New Liskeard, Ont., Can.
Smith, R. D., Public Service Co. of No. Ill., Evanston, Ill.
Snow, H. E., (Member), Gibbs & Hill, New York, N. Y.
Soule, F. M., Carnegie Institution of Washington, Washington, D. C.
Stacey, L. B., (Member), University of British Columbia, Vancouver, B. C., Can.
Stevenson, A. C., Hecla Mining Co. & Sullivan Mining Co., Wallace, Idaho
Stewart, L. B., Shawinigan Water & Power Co., Shawinigan Falls, Que., Can.
Stith, R. G., Kansas City Power & Light Co., Kansas City, Mo.
Strelzoff, J. A., 170 Claremont Ave., New York, N. Y.
Taber, L. E., New Bedford Vocational School, New Bedford, Mass.
Talbott, J. E., Stevens & Wood, Inc., Jackson, Mich.
Teare, B. R., Jr., University of Wisconsin, Madison, Wis.
Terkelson, G. A., Atlantic Refining Co., Philadelphia, Pa.
Thibeault, A., Canada Power & Paper Corp., Grande Mere, Que., Can.
Thomas, G. C., Hydro-Electric Power Comm., Toronto, Ont., Can.
Turnbull, A. G., (Member), Commonwealth Edison Co., Chicago, Ill.
Valentine, D. O., American Tel. & Tel. Co., Cleveland, Ohio
Wahlstrom, R. D., Western Union Tel. Co., Chicago, Ill.
Wardner, H. E., 4 Academy St., Saranac Lake, N.Y.
Waring, M. L., General Electric Co., Schenectady, N. Y.
White, E. T., Jr., 9315–107th St., Richmond Hill, N. Y.
Wickstrom, C. S., Commonwealth Edison Co., Chicago, Ill.
Willis, E. S., Bell Telephone Laboratories, Inc., New York, N. Y.
Winemiller, H. R., Commonwealth Edison Co., Chicago, Ill.
Wollaeger, L. A., Globe Electric Co., Milwaukee, Wis.
Wyland, E. E., Mountain States Tel. & Tel. Co., Boise, Idaho
Total 148.

Foreign

Bruford, S. J., (Member), Punjab P. W. Dept., Jogindar Nagar, Kangra District, No. India
Davis, N. E., (Member), Marconi Wireless Telegraph Co., Ltd., Chelmsford, Essex, Eng.
Dean, G. H., Corrie, Old Shoreham Road, Shoreham-by-Sea, Eng.
Husain, Ziarat B., Principal, Electrical Engineering Dept., Jagatjit Birdwood Engg., College, Amritsar; for mail, Allahabad, U. P., India
Josse, H., Ste. Electricite de Paris, Saint Denis, France
Mukerji, K. P., Thana Electric Supply Co. Ltd., Thana, Bombay, India
Mulqueen, B. A., Rio de Janeiro Tramway, Lt & Pr. Co. Ltd., Rio de Janeiro, Brazil, So. America
Pettigrew, J., All America Cables Inc., Cali, Colombia, So. America
Pyper, D., Braden Copper Co., Rancagua, Chile, So. America
Total 9.

STUDENTS ENROLLED

Abella, Roman V., University of Washington
Adams, Eric G., McGill University
Alger, Blandford A., Cooper Union
Anderson, Hugh V., Oklahoma Agricultural & Mechanical College
Anderson, John W. Jr., University of Notre Dame
Angus, F. William, McGill University
Asmus, William F., Armour Institute of Tech.
Austin, Lewis H., Iowa State College
Bacon, Walter M., Cornell University
Badger, Harold R., University of Washington
Baker, George W., Armour Institute of Tech.
Ballou, Frank M., Iowa State College
Barlow, Robert J., University of Michigan
Bartley, Edward A., University of Notre Dame
Bell, Graham A., Jr., McGill University
Berry, Wayne J., Missouri School of Mines & Metallurgy
Betz, Willie G., Louisiana State University
Beveridge, William B., Newark, College of Eng.
Bigelow, Folger H., Armour Institute of Tech.
Blahna, Charles, Armour Institute of Technology
Blomquist, Sigurd, University of Utah
Boggess, Bill, Kansas State Agricultural College
Bogowicz, Chester S., Armour Institute of Tech.
Bonilla, Charles F., Columbia University
Bossler, Edward C., Montana State College
Braga, Felix J., University of Minnesota
Branson, Harry, Jr., University of Pennsylvania
Brant, T. J., University of Toronto
Braunwarth, William W., University of Penn.
Breneman, Alfred M., Kansas State Agri. College
Brieger, Earl W., University of Notre Dame
Briggs, Maynard R., University of Minnesota
Brown, Homer, University of Minnesota
Browne, Townsend D., Rensselaer Polytechnic Institute
Bruncke, Harry P., University of Minnesota
Buehling, Norman D., Armour Inst. of Technology
Bugenstein, Arthur A., University of Minnesota
Burns, James A., Cooper Union
Carleton, Stephen O., Brown University
Carsberg, Edgar C., University of Minnesota
Causey, Hoyt C., Clemson Agricultural College
Chalek, Isadore, University of Minnesota
Chatfield, Gurdon F., Rensselaer Polytechnic Inst.
Christiansen, John, University of Notre Dame
Cillie, Charl D., Massachusetts Institute of Tech.
Clancy, Thomas, Northeastern University
Clark, Everett O., University of Detroit
Clark, Hardin T., University of Louisville
Clark, William R., University of Pennsylvania
Clarke, Frederick E., McGill University
Clema, John M., University of Nebraska
Cleveland, Arthur L., University of Nebraska
Cline, W. Kenneth, Clarkson College of Tech.
Coats, Arlie, Kansas State Agricultural College
Conger, George B., Jr., Cornell University
Conrad, Warren D., Eng. School of Milwaukee
Converse, Henry A., 3rd, Virginia Polytechnic Institute
Cooney, William F., Clarkson College of Tech.
Cordua, Carl D., College of the City of New York
Cover, Earl J., Kansas State Agricultural College
Cox, Ray D., University of Florida
Crawford, James M., McGill University
Credle, Alexander B., Cornell University
Criswell, William L., Kansas State Agr. College
Crockett, Alton E., University of Maine
Crouter, Leslie E., Montana State College
Curd, John P. Jr., University of Louisville
Curry, Arnet A., Purdue University
Curtis, William G., Oklahoma A. & M. College
Dale, Edwin E., University of Washington
Damaskin, Nicholas J., University of Pittsburgh
Danziger, Samuel, Columbia University
Datshkovsky, Eleazar, Lewis Institute
Davis, George P., University of Nebraska
Davis, Harry V., University of British Columbia
DeBaene, E. C., University of Notre Dame
Defina, Frank P., Northeastern University
Denny, Fred F., University of Arizona
Diedrich, Erwin H., University of Minnesota
Dollenmaier, Jack M., Armour Institute of Tech.
Douglas, Norvel, Kansas University
Douglass, William E., University of Texas
Dudley, Beverly, Armour Institute of Technology
Duffy, John B., Northeastern University
Dunn, Raymond C., Georgia School of Tech.
Dylewski, Thaddeus J., Armour Institute of Tech.
Earl, John C., University of Illinois
Eberts, Hermann L., McGill University
Effertz, Orman G., University of Minnesota
Ellicock, Albert B., University of Arizona
Emlein, Harold, University of Minnesota
Emmert, John L., University of Notre Dame
Engelhardt, George B., Cornell University
Erdos, Eugene J., College of the City of New York
Erickson, Bert E., University of Utah
Escott, Ralph E., Armour Institute of Technology
Ewald, Earl, University of Minnesota
Ewy, Albert, University of Minnesota
Fagergren, Alvin, University of Utah
Fair, Irvin E., Iowa State College
Farel, Gordon M., University of Minnesota
Fenton, Ransford W., University of Minnesota
Filmer, Walter L., Jr., Armour Institute of Tech.
Fitzgerald, Edmund, University of Detroit
French, Edwin C., University of Minnesota
Frye, Charles C., Oklahoma A. & M. College
Fulkerson, William H., Rensselaer Poly. Inst.
Funk, Howard N., Engg. School of Milwaukee
Funk, James W. Jr., University of Utah
Ganzer, Edward A. W., Armour Institute of Tech.
Gary, Ronald M., Montana State College
George, William D., Georgia School of Technology
Gibson, Gordon P., University of Nebraska
Gieringer, Carl K., University of Arizona
Gillis, Norman S., Rensselaer Polytechnic Inst.
Goar, Roy, University of Arizona
Goggin, Patrick J. Jr., University of Notre Dame
Goldberg, Yale, Iowa State College
Good, Carl T., Engineering School of Milwaukee
Grabert, Harmond T., University of Minnesota
Green, Arthur T., University of Minnesota
Greimann, Maurice, Iowa State College
Grimm, Richard J., University of Notre Dame
Grohoski, Alexander F., Mississippi A. & M. College
Groo, Earl R., Cornell University
Hale, James A., Ohio State University
Hamilton, Robert W., McGill University
Hanke, Edwin W. F., Armour Institute of Tech.
Hastad, C. Jerome, University of Minnesota
Hauge, Morris J., University of Minnesota
Hays, Vernon E., University of Nebraska
Henderson, Frank, University of Arizona
Hendrickson, Martin L., Oklahoma A. & M. College
Henrikson, Frank W., Brooklyn Polytechnic Inst.
Henschke, William, Cooper Union
Herklotz, Ernest A., Rensselaer Polytechnic Inst.
Herndon, Paul H. Jr., George Washington Univ.
Hershey, Vaughn F., Iowa State College
Hickenlooper, Miller M., Iowa State College
Hicks, Warren W., University of Wyoming
Highfield, Frank A., University of Detroit
Hill, John O., Cornell University
Himebrook, Frank S., Ohio State University
Hoblitzell, Austin B., University of Washington
Hoffmann, Walter G., Cornell University
Horn, Tory, University of Washington
Hornberger, Frederic W., University of Illinois
Hrubec, Theodore T., University of Notre Dame
Huang, Hui, Purdue University
Hubbell, M. Fred, University of Missouri
Hughes, William D. Jr., Mississippi A. & M. Coll.
Humberd, Ralph S., University of Nebraska
Hunt, Donald N., Rensselaer Polytechnic Inst.
Hylton, Clarence W., Virginia Polytechnic Inst.
Inslerman, Hans E., Cooper Union
Jackson, Edward S. Jr., University of Michigan
Janiszewski, Stephen, Armour Institute of Tech.
Jay, James, Armour Institute of Technology
Jay, Stanley P., Ohio State University
Jerahian, Puzant H., Drexel Institute
Johnson, Carl H., Armour Institute of Technology
Johnson, Floyd M., University of Minnesota
Johnson, James O., Rensselaer Polytechnic Inst.
Johnson, Lambert L., Purdue University
Johnson, William P., Virginia Polytechnic Inst.
Jones, James W., Pennsylvania State College
Karageorges, George P., University of Minnesota
Keener, Charles E., Drexel Institute
Kelton, Kenneth, University of Arizona
Kemper, George W., Iowa State College
Kendall, Donald B., University of Minnesota
Killian, Leo G., University of Arizona
Kingcade, Paul M., Ohio State University
Kleinkauf, James D., University of Nebraska
Knittel, Kilian, Armour Institute of Technology
Knott, Gilbert R., Rose Polytechnic Institute
Knudsen, E. Phillip, Jr., Carnegie Inst. of Tech.
Kocher, Addis E., Massachusetts Inst. of Tech.
Krasnow, Shelley, College of the City of New York
Kuglin, Charles R., Armour Institute of Tech.
Laird, Orville, Texas A. & M. College
Lange, Fred E., University of Nebraska
Lawrence, George F., University of Detroit
Lawrie, David E., University of Florida
Ledvina, Joseph P., Johns Hopkins University
Lenk, Herman P., Newark College of Engineering
Leonard, Stephen C., Rensselaer Polytechnic Inst.
Lethco, Joseph W., Oklahoma A. & M. College
Lethert, Carl W., University of Minnesota
Light, John C., Georgia School of Technology
Linn, George J., University of Arizona
Lockwood, Robert R., Carnegie Institute of Tech.
Loney, Francis M., University of Notre Dame
Loomis, Francis E., Lehigh University
Loufek, Leonard H., Iowa State College
Lovejoy, Ervie E., University of South Dakota
Lowens, Milton, Cornell University
Lynch, Carroll F., Cornell University
Lynde, Carleton J., Jr., McGill University
MacDuff, Leo, Engineering School of Milwaukee
MacKay, Harry A., Purdue University
Macris, C. A., University of Arizona
Malar, Paul P., Drexel Institute
Mangum, Otto K., University of Arizona
Manning, Thomas E., University of Pennsylvania
Manzo, Ricardo, University of Arizona
Marston, George, Oklahoma A. & M. College
Matheson, Donald R., Armour Institute of Tech.
Matthiesen, Paul, Oklahoma A. & M. College
Mayers, Harry R., University of Maine
McArthur, Sidney E., Montana State College
McBride, John A., University of Arizona
McCarthy, William C. Jr., Univ. of Notre Dame
McInerney, Richard, Armour Institute of Tech.
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Network Transformers.—Bulletin 1807, 12 pp. Describes Westinghouse network transformers and accessories for secondary alternating-current network systems. Westinghouse Electric & Manufacturing Co., East Pittsburgh.

Fans.—Bulletins 17-2 to 17-6. A series of 2-page bulletins describing "Century" stationary and oscillating fans; and ceiling fans for alternating and direct current. Century Electric Company, 1827 Pine Street, St. Louis.

Pulverized Fuel Equipment.—Bulletin, 52 pp., describes the Aero Unit System of pulverized fuel firing and covers the development and application of the unit system for firing pulverized fuel. Foster Wheeler Corporation, 165 Broadway, New York.

Cable Accessories.—Catalog 741, 46 pp. Describes "Standard" jointing and miscellaneous materials, including insulating compounds for cable terminals, junction boxes and cable joints, paper jointing tubes, copper connectors, tapes, lead sleeves, etc. Standard Underground Cable Company, 17th & Pike Streets, Pittsburgh.

Power Plant Instruments.—Bulletin, 48 pp., "Power Plant Instrument Data Book." Outlines one hundred and five applications of instruments to the steam power plant for measuring temperatures, pressures, flows, liquid levels and speeds. The Brown Instrument Company, Wayne and Roberts Ave., Philadelphia.

Switching Equipment.—Bulletin 312, 36 pp., with prices effective March 1, 1929. Contains complete engineering data, descriptive information, list of quantity prices of outdoor type standard and switching equipment for 7500, 12,000 and 15,000 volts. James R. Kearney Corporation, 4228 Clayton Avenue, St. Louis.

Automatic Valve Control.—Bulletin, 20 pp. and price list. Describes Bristol's automatic electric control valves, motor operated and magnet types. Applications of such apparatus for fuel, gas, air, steam and water are outlined. Illustrations and brief descriptions of temperature recording instruments are included. The Bristol Company, Waterbury, Conn.

Transformers.—Bulletin 161, 20 pp. Contains instructions for the installation and operation of power and distribution transformers. The bulletin also covers such subjects as location of transformers, their storage, handling and installation; drying core and coils; drying and testing oil; proper operating temperature. Wagner Electric Corporation, 6400 Plymouth Street, St. Louis.

Lightning Protection.—Bulletin C-1737-D, 20 pp., "Effective Lightning Protection." Describes the nature and magnitude of transient voltages on electrical systems, lightning arrester requirements and applications. Of special interest is the information on oscillograph studies of lightning phenomena and the economic value of lightning protection. The oscillograph studies described were made by the Westinghouse Company in the Tennessee mountains on a 154-kv. line of the Knoxville Power Company. Westinghouse Electric & Manufacturing Company, East Pittsburgh.

Twisted Service Cable.—Bulletin, 36 pp. Describes twisted service cable for house service and street lamp connections. It contains a special section on specifications with a detailed table of weights and sizes. Instructions for the proper installation of cable from the poles to the house are illustrated aud described. This booklet was edited by W. K. Vanderpoel, vice-president and executive engineer of the Okonite Company, and a recognized authority on outside plant construction. The Okonite Company, Passaic, N. J.

NOTES OF THE INDUSTRY

The Wagner Electric Corporation, St. Louis, has added K. G. Baker to its Cincinnati sales force. Mr. Baker was previously connected with the Century Electric Company and with the Fulton Iron Works.

The Ohio Brass Company, Mansfield, Ohio, has opened a new office at 2143 Railway Exchange Building, 611 Olive Street, St. Louis. This office will be the headquarters of H. W. Kilkenny district sales manager for the company in the St. Louis territory.

Rochester Electric Products Corporation, 87 Allen Street, Rochester, N. Y., manufacturers of the Diverter Pole Generator, described in a paper which was recently published in the JOURNAL, has appointed the H. M. Thomas Company, with offices at 589 Howard Street, San Francisco, and 912 East 3rd Street, Los Angeles, as California sales representative.

General Electric Annual Report for 1928.—Earnings of the General Electric Company for 1928 amounted to $54,153,806, according to the annual report of the company. Orders received during the year 1928 were $348,848,512, compared with $309,784,623 in 1927, an increase of 13 per cent, and unfilled orders at the end of the year were $72,953,000, compared with $68,916,000 at the close of 1927, an increase of six per cent.

The Roller-Smith Company, 12 Park Place, New York, has made the following additions to its sales organization: Jackson Brown, Jr., 701 Kittridge Building, Denver, is representative in Colorado, Utah, Wyoming and northern New Mexico: The Manila Machinery & Supply Company, Inc., Manila, P. I., is representative in the Philippine Islands. Both of these new representatives will handle the Roller-Smith Company's line of electrical measuring instruments, relays and circuit breakers.

The Synthane Corporation has completed the erection of its plant at Oaks, near Philadelphia, and is now in production of laminated Bakelite products in sheets, rods, tubes and fabricated parts. The plant, built solely for the production of laminated Bakelite materials, is of the most modern construction and located on the Pennsylvania Railroad System. The Synthane Corporation is represented by H. G. Blauvelt, Tribune Building, New York; J. B. Rittenhouse, 32-40 South Clinton Street, Chicago, and C. E. White & Company, Bulkley Building, Cleveland.

Westinghouse Electric's Best Year.—The business of the Westinghouse Electric & Manufacturing Company during the year 1928 was the best of any twelve months in its history, according to the company's report recently made public. Sales billed for the year were $189,050,302, and the net income was $20,814,940, which figures exceed previous records by $3,500,000 and $2,700,000 respectively. The value of unfilled orders on December 31, 1928, was approximately $47,000,000. During the latter nine months of the year, the value of orders received exceeded by almost $20,000,000 that of the same period during 1927, due largely to the increased demand for radio products and industrial motor apparatus.

Burndy Engineering Co., Inc., 10 East 43rd St., New York, manufacturers of equipment for the high tension bus, has appointed the following representatives for their respective territories: Boston, J. J. Costello, 201 Devonshire St.; New York, J. Leo Scanlon, 50 Church St.; Buffalo, J. Leo Scanlon, 487 Ellicott Square; Philadelphia, The Bradley Co., 2401 Chestnut St.; Pittsburgh, Henry N. Muller Co., First National Bank Bldg; Atlanta, H. Douglas Stier, 101 Marietta St.; Cleveland, A. D. Fishel Co., 942 Engineers Bldg.; St. Louis, J. P. Lane, 471 Paul Brown Bldg.; Dallas, Elgin B. Robertson, 711 Southwestern Life Bldg.; Denver, Joy & Cox, Inc., 314 Tramway Bldg.; San Francisco, H. M. Thomas Co., 163 Second St.; Seattle, Fred W. Carlson, 424 Dexter Horton Bldg.; Los Angeles, L. W. Thompson Co., 912 East 3rd St.; Chicago, Frank P. Withers, 2057 Jarvis Ave.